

AFFECTIVE INFORMATION PROCESSING
AND ANXIETY: ATTENTIONAL BIAS AND
SHORT-LEAD INTERVAL STARTLE MODIFICATION

By

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For Susie, Monty, & Dozer.

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TABLE OF CONTENTS

	<u>page</u>
ACKNOWLEDGMENTS	IV
LIST OF TABLES	IX
LIST OF FIGURES	X
ABSTRACT	XII
 CHAPTER	
1 INTRODUCTION	1
Anxiety Subtypes	2
Anxiety and Attentional Bias to Threat	3
Startle Eyeblink Modification and Attentional Bias	5
The Startle Reflex	5
Startle stimulus parameters	6
Electrode placement	7
Signal acquisition, conditioning, and processing guidelines	8
Response definition and scoring	9
Primary acoustic startle circuit	10
Modification of the Startle Eyeblink Reflex	10
Prepulse Inhibition	12
Protection of processing	13
Sensorimotor gating	14
Automatic and controlled attentional processing	15
Pulse Facilitation	16
Application of Startle Modification to Examine Anxiety	16
Application of Startle Modification to Examine Attentional Bias	17
Limitations	18
Experimental Objectives, Description, and Hypotheses	19
Hypotheses	20
 2 REVIEW OF ATTENTIONAL BIASES LITERATURE: CONCEPTUAL FRAMEWORK, METHODOLOGY, AND THEORETICAL ACCOUNTS	 21
Timing Is Everything	21
Overview of Attention	30
Selective Attention	30

It's a party.....	31
Early filter models of selective attention.....	31
Resource Theories	36
Single resource views	36
Multiple-resource views	39
Visual attention	40
Metaphors of Visual Attention	43
Visual Attention Paradigms and Feature Integration Theory	45
Feature-Integration Theory.....	47
Location cueing paradigms	49
Summary.....	51
Review of Cognitive Accounts of Anxiety: Methodological Considerations	52
Stroop Paradigm	52
Dot-Probe Paradigm	57
Visual Search Tasks	59
Exogenous Cueing and Inhibition of Return Tasks.....	67
Theoretical Accounts of Anxiety and Corresponding Models	70
Biased Attentional Direction Account.....	71
Connectionists Networks in Anxiety.....	72
Strategic Monitoring for Threat Account	75
Cognitive-Motivational (Vigilance to Threat) Account	78
Enhanced Dwell-Time (Difficulty to Disengage)	80
Evolutionary Preparedness Account.....	83
Biphasic Theory and Natural Selective Attention	85
Summary of Theories and Discussion	89
 3 STARTLE EYEBLINK MODIFICATION AND ANXIETY: SHORT LEAD INTERVAL STARTLE INDEXES EARLY AFFECTIVE PROCESSING OF LEXICAL STIMULI.....	93
Method	93
Participants	93
Materials, Apparatus, and Procedure.....	94
State-Trait Anxiety Inventory	94
Positive Affect - Negative Affect Schedule	95
Lead stimuli.....	95
Apparatus	98
Physiological Data Collection and Reduction.....	98
Procedure.....	100
 4 RESULTS	104
Multivariate Tests.....	104
Blink Magnitude Univariate Tests.....	107
Onset Latency Univariate Tests.....	109

5	DISCUSSION.....	111
	Instrumentation Diagnostics	113
	Limitations.....	118
	Directions for Future Research, Summary, and Conclusions.....	111
APPENDIX		
A	INSTITUTIONAL REVIEW BOARD APPROVAL.....	122
B	INFORMED CONSENT.....	123
C	POWER CALCULATION FOR MULTI-FACTOR MIXED DESIGNS.....	126
	LIST OF REFERENCES.....	128
	BIOGRAPHICAL SKETCH.....	146

LIST OF TABLES

<u>Table</u>	<u>page</u>
3-1. Participant characteristics listed by group.	94
3-2. The table presents a prototypical trial block.....	102
4-1. Questionnaire comparisons by Group.	105
4-2. Means and standard deviations for startle eyeblink response probabilities listed by Group and Lead Interval as a function of Word Category.	106
4-3. Means and standard deviations for startle eyeblink response magnitude listed by Group and Lead Interval as a function of Word Category.	106
4-4. Means and standard errors for startle blink magnitude values listed by Lead Interval and Category adjusted by State Anxiety.	109

LIST OF FIGURES

<u>Figure</u>	<u>page</u>
1-1. Prevalence rates of common anxiety disorders. Percentages reflect data based on United States Census resident population estimate of 143.3 million, age 18 to 54. ...1	1
1-2. Raw blink EMG waveform and the transformation at each processing step using the recommended procedure by Van Boxtel and Blumenthal (2003).8	8
1-3. Common terms used in startle modification research..11	11
1-4. Major divisions of startle eyeblink modification paradigms.12	12
2-1. The Evaluative Space Model (depicted) is useful to illustrate how various local conditions may influence the dispositional attributes of an organism.26	26
2-2. The Defense Cascade Model by Lang, Bradley, & Cuthbert (1997).29	29
2-3. Broadbent' information-processing model of selective attention.....33	33
2-4. Norman's pertinence model of attentional selection.35	35
2-5. Kahneman's resource model of attention.37	37
2-6. Hypothetical POC curve.38	38
2-7. A three-dimensional illustration of Wickens' Multiple Resource Theory.40	40
2-8. Shows scan path and fixations for two images by a single participant.44	44
2-9. Example of simple visual search task.....46	46
2-10. Feature-integration model by Treisman & Gormican (1988).....48	48
2-11. Original cost/benefit paradigm used in Posner et al. (1978).51	51
2-12. Variants of the Stroop task. A) Traditional Stroop, B) Emotional Stroop, C) Directional and Emotional Counting Stroop.....54	54
2-14. Facial stimuli used by Öhman et al. (2001a).....62	62

2-15. The inhibition of return paradigm has been modified to evaluate disengagement by replacing standard light cues with emotionally valenced picture or word stimuli...	69
2-16. Williams et al. model of attentional bias.	71
2-17. Network used by Cohen et al. (1990) to simulate the color naming interference effects observed in Stroop tasks.	74
2-18. Wells and Matthews Self-Regulatory Executive Function model (S-REF).	77
2-20. Shows the postulated pattern of vigilance/avoidance for an individual with low trait anxiety. This model contrasts with Matthews' interaction model.....	81
2-21. Öhman's information-processing model of anxiety.	83
3-1. Shows the distribution of word categories for valence and arousal based on normative SAM ratings for all subjects.....	97
3-2. Histogram of STAI-Trait scores by frequency from screening samples in the Spring 2005 term.....	100
4-1. Polar plot of each word category and lead interval representing proportion of difference scores for all subjects ($N = 54$).....	107
4-2. Show the blink habituation curve for both groups for each presentation of the startle probe during the ITI.	108
4-3. Polar plot of each word category and lead interval representing onset latency for all subjects ($N = 53$).	110
3-6. The top panel presents an intensity map of time delay between lead stimulus appearance and onset of the startle pulse in relative temporal distance from trial specified lead interval.....	115

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Contemporary perspectives of anxiety suggest attentional biases toward threat are hallmark symptoms of a wide range of emotion-related disorders. While theoretical debate has surrounded the nature of attentional biases as related to anxiety problems, theorists concur that clarifying the nature of attentional biases is vital for the specification of appropriate and effective interventions. In the current study, a startle modification paradigm was employed to clarify questions pertaining to the early time course of how threatening information is processed. Low and highly trait anxious students were exposed to 4 different lead intervals and 5 different word categories. Partially supporting previous findings, a significant Group x Category x Lead Interval interaction was obtained for blink magnitude. Follow-up comparisons confirmed that high trait anxious subjects exhibited significantly greater blink facilitation relative to neutral words at a lead interval of 50 ms, whereas this difference was not observed for low trait anxious controls. Earlier studies suggesting that blink facilitation to threat is maximal at 60 ms relative to neutrals

were not supported. Further, highly trait anxious participants also exhibited blink facilitation to low arousing pleasant words, relative to neutral words at 50 ms.

CHAPTER 1 INTRODUCTION

Anxiety disorders continue to collectively represent the single largest mental health problem in the United States (Barlow, 2002). Based on 1998 census data, anxiety disorders are estimated to afflict approximately 19 million American adults ages 18 to 54, with women twice as likely to be affected as men (Figure 1-1; National Institutes of Health, 2002). In a study commissioned by the Anxiety Disorders Association of America (ADAA), anxiety disorders were estimated to cost the United States over \$42 billion in 1990 (Greenberg et al., 1999).

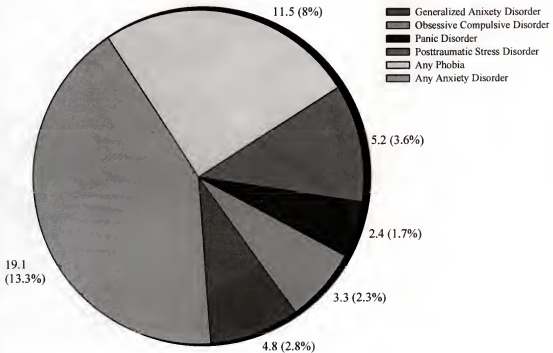


Figure 1-1. Prevalence rates of common anxiety disorders. Percentages reflect data based on United States Census resident population estimate of 143.3 million, age 18 to 54.

Anxiety Subtypes

Anxiety, in the pathological sense, can be defined as a “psychophysiological phenomenon experienced as a foreboding dread or threat to human organism whether the threat is generated by internal, real or imagined dangers” (Emilien, Durlach, Lepola, & Dinan, 2002, p. 1). While a certain amount of anxiety is considered a normal response to a multitude of circumstances of daily life, pathological anxiety can be debilitating.

Subtypes of anxiety disorders are differentiated by their individual characteristics. The *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV-TR; American Psychiatric Association, 2000) provides the following diagnosis under the classification of anxiety disorders: (1) panic disorder (PD) with agoraphobia, (2) PD without agoraphobia, (3) agoraphobia without a history of PD, (4) specific phobia (SP), (5) social phobia or social anxiety disorder (SAD), (6) obsessive-compulsive disorder (OCD), (7) post-traumatic stress disorder (PTSD), (8) acute stress disorder (ASD), (9) generalized anxiety disorders (GAD), (10) anxiety disorder due to general medical condition, (11) substance induced anxiety disorder, and (12) anxiety disorder not otherwise specified. An abridged synopsis of each type is listed below.

- **Panic disorder (1-3):** individuals experience periodic unexpected panic attacks.

Panic disorder can occur coupled with agoraphobia (the avoidance or apprehension of places or situations), or without agoraphobia; or agoraphobia can occur in absence of a panic disorder.

- **Specific phobia (4):** anxiety elicited by the anticipation or presence of a feared object or situation.
- **Social phobia (5):** anxiety provoked by exposure to social or performance situations.

- **Obsessive-compulsive disorder (6):** individuals with OCD experience recurrent thoughts or urges (obsessions) that cause a great deal of anxiety coupled with repetitive behaviors (compulsions) that aim to reduce anxiety or distress.
- **Post-traumatic stress disorder (7):** sufferers of PTSD experience various symptoms after a traumatic situation or event. According to the DSM-IV-TR (APA, 2000), these symptoms may include reliving the event or avoiding stimuli associated with the encounter altogether.
- **Acute stress disorder (8):** (similar to PTSD) development of pathological anxiety in response to a traumatic situation or event. The major difference between the two is that individuals diagnosed with ASD do not experience symptoms for longer than 1 month.
- **Generalized anxiety disorder (9):** characterized by excessive worry or anxiety which is not easy to control.
- **Anxiety disorder due to a general medical condition (10):** symptoms of anxiety determined to be a physiological result of a medical condition.
- **Substance-induced anxiety disorder (11):** anxiety symptoms determined to be a physiological consequence of the systemic effects of a drug or chemical agent.
- **Anxiety disorder not otherwise specified (12):** a classification for disorders with excessive anxiety or avoidance not meeting the criteria for another disorder.

Anxiety and Attentional Bias to Threat

Attentional bias to threatening information is routinely implicated as a cardinal vulnerability in many cognitive accounts of anxiety (Beck, 1976; Bower, 1981; Mogg & Bradley, 1998; Wells & Matthews, 1994; Williams, Watts, MacLeod, & Matthews, 1988).

In recent years, cognitive formulations of anxiety have made much progress in establishing both the theoretical and methodological foundations for understanding the nature of attention in anxiety and related disorders. These accounts generally argue that biases of attention toward threat may translate into the development and perpetuation of clinically anxious states (Mogg et al., 2000). Evidence to substantiate this position has been widely supported by three primary approaches aimed at assessing attention to threatening information via interference (Bradley et al., 1995; MacLeod & Rutherford, 1992; Williams et al., 1996), probe detection (Bradley et al., 1998; Broadbent & Broadbent, 1988; Fox, 1993, 2002; MacLeod et al., 1986; MacLeod & Mathews, 1988; Mogg & Bradley, 1999), and visual search (Hansen & Hansen, 1988; Öhman et al., 2001a, 2001b; Tipples et al., 2002).

Within this literature, however, there is considerable heterogeneity among researchers who argue that certain anxiety disorders are demarcated exclusively by the attentional capture of threat cues (Mogg & Bradley, 1998; Williams et al., 1988; 1996), a propensity to monitor for threat (Wells & Matthews, 1994; 1996; Matthews & Wells, 1999), or the delayed disengagement from threat following detection (Amir et al., 2003; Derryberry & Reed, 2002; Koster, Crombez, Verschuere, & Houwer, in press; Fox et al., 2001; 2002; Yiend & Mathews, 2001). Generally speaking, these points of disagreement center on the *temporal course of attentional allocation following the presentation of stimuli that represent threat*.

While each of the major accounts have clear conceptual and theoretical differences, they similarly suffer from weak inferences drawn from a limited number of paradigms, and more importantly, the sensitivity of these paradigms to resolve the real-

time evaluation of the chronometry of attentional biases. While these and other issues are addressed in chapter 2, it is important to note that many of the core theoretical pillars of these models have been somewhat limited by relying solely on behavioral techniques to assess information-processing, and more importantly, attentional allocation. Moreover, it is often the case that observations of attentional bias to threat fall under the pretext of strict stimulus characteristics. Current theoretical frameworks inadequately account for the failure to observe biases to stimuli that do not represent threat. Thus, explaining the temporal chronometry of attentional allocation and accounting for individual differences in the perception of threat represent two of the major theoretical challenges to cognitive theories of anxiety.

Startle Eyeblink Modification and Attentional Bias

Researchers have occasionally departed from the interference (e.g., Stroop), probe detection, or visual search tasks commonly employed in the attentional bias literature. The use of startle eyeblink modification techniques, for instance, has been instrumental in understanding the fear system in both human and animal models of emotion (Davis, Walker, & Lee, 1999; Lang, Bradley, & Cuthbert, 1990), and has also been more recently applied to evaluating questions pertaining to attentional bias. However, to fully understand how startle modification techniques can be used in the context of attentional bias, information pertinent to the startle reflex, including its measurement, neurophysiology, and research application are presented.

The Startle Reflex

The startle reflex is a quick, stereotyped response to a sudden and intense sensory event. The reflex is thought to serve a protective function given the characteristic contraction and flexion of the body, which is thought to protect vital organs from attack

or blow (Koch, 1999). Early work by Landis and Hunt (1939) documented the startle response in humans by firing a single pistol shot from behind subjects, capturing the reflex using high-speed photography.

Startle stimulus parameters

Needless to say, both startle elicitation and measurement techniques have changed drastically with time. The signal eliciting the startle reaction can arise from auditory, visual, or cutaneous sources (e.g., airpuff to the eye, electrical stimulation), with each source varying in the stimulus parameters that ultimately contribute to the latency, amplitude, or probability of the response (for review, see Berg & Balaban, 1999). While several methods are available to researchers interested in studying eyeblink startle, the focus of this and following sections will be on parameters related to *acoustic startle in humans*.

Numerous studies have documented the stimulus parameters necessary to evoke startle, and have demonstrated how different stimulus characteristics contribute to the eyeblink startle response. According to Berg and Balaban (1999), *rise time*, *intensity*, *duration*, and *bandwidth* are the four primary properties of auditory stimuli having marked effects on the evoked startle response. *Rise time* refers to the time needed for a signal to transition from a given intensity until reaching a specified threshold. Near instantaneous rise time has been shown to be a critical component in eliciting startle (Błaszczuk, 2003; Blumenthal, 1988; Hoffman & Ison, 1980). Blumenthal and Berg (1986) have shown that startle elicitation fails for very intense auditory stimuli that have long rise times. In humans, Berg (1973) suggests that the integrated energy over 10-12 ms, and not the peak intensity is critical to eliciting startle. Given low rise time, the signal *intensity* needed to elicit startle should be considered jointly with response probability

(Berg & Balaban, 1999). For example, Berg (1973) reported that startle can be elicited for signals as low as 84 dB (A).¹ Berg, however, cautions that reports of startle responses found as low as 50 dB (A), as in Blumenthal and Goode (1991), often have extremely low response probabilities. Both signal *duration* and *bandwidth* necessary to evoke startle has been systematically investigated by Blumenthal and Berg (1985). The researchers suggest that broadband white noise approximately 32 ms in duration is more effective than a single tone at equal intensities, however shorter tones are more effective at eliciting startle at shorter durations (< 16 ms).

Electrode placement

The startle reflex is most commonly assessed by measuring the eyeblink component of the reflex through electromyography (EMG) of the orbicularis oculi muscle in humans. Berg and Balaban (1999) recommend placement of one electrode immediately below the eye while the participant is looking straight ahead, and the other 1-2 cm (center-to-center) lateral to the first. Similarly, Fridlund and Cacioppo (1986) recommend placing the first electrode 1 cm below the exocanthion and the second electrode 1 cm medial, and slightly inferior to the first.

¹ A bel (B) is a dimensionless unit that represents the logarithm of the ratio between two power levels, thus, $B = \log_{10}(P1/P2)$. Because the bel is too large and therefore impractical to express many everyday relationships, the decibel (dB), equivalent to 0.1 B is more commonly used. The decibel is often used in acoustics to quantify sound levels relative to some reference. In certain cases, researchers will define this reference as sound pressure level (SPL), which is equivalent to 20 micropascals (μP), or the minimum perceptible sound (MPS) of human hearing, roughly equal to 1 picowatt per square meter (pW/m^2) or as $0.0002 \text{ dyne}/\text{cm}^2$, which has been internationally determined as a continuous tone at a frequency between 2000 and 4000 Hz heard by someone with good hearing. A dyne is a unit of force equal to the force needed to accelerate 1 gram of mass at a rate of $1 \text{ cm}/\text{s}^2$ and a Pascal is a unit of pressure equivalent to 1 newton per square meter (N/m^2). Because the ratio from MPS to an intensity that causes damage to the ear is extremely large, the decibel is useful metric in handling this range. In certain cases the abbreviation dB will be followed by an A, B, or C. These letters correspond to weighting networks on sound level meters, which approximate the psychophysical changes in sensitivity to the ear at different frequencies. Sound intensities taken in reference to SPL are considered unweighted, but most closely approximate C-weighting. A-weighting is often used when the distribution of power to different frequency is similar. Hence, for startle stimuli that consist of broadband white noise, A-weighting is commonly used (Truax, 1999).

Signal acquisition, conditioning, and processing guidelines

Van Boxtel and Blumenthal (2003) made several suggestions regarding analog and digital processing of eyeblink startle. First, although sampling rate will vary as a function of filter settings, they recommend a sampling rate of at least 1000 Hz, to allow for sufficient time resolution when determining onset and peak latency once the raw EMG waveform has been smoothed. Additionally, Van Boxtel, Boelhouwer, and Bos (1998) advise a passband setting of 28-500 Hz using a 4th order Butterworth filter or a digital finite response filter (FIR) with 101 coefficients and a Hamming window as optimal for acoustic eyeblink EMG (Figure 1-2 for an example of the waveform following transformation). Once the EMG signal has been integrated, van Boxtel and Blumenthal furthermore recommended a similar setting for signal smoothing using a 40 Hz cutoff that is suitable for most startle applications.

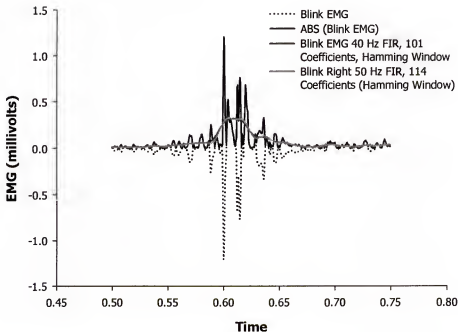


Figure 1-2. Raw blink EMG waveform and the transformation at each processing step using the recommended procedure by Van Boxtel and Blumenthal (2003).

Response definition and scoring

Van Boxtel (2004) suggested the following dependent variables may be extracted from a processed EMG waveform to address numerous research questions:

- **Onset latency:** the time from stimulus onset until response initiation. Criteria for response initiation may vary, such as two standard deviations above baseline or a change in slope over a specified period (e.g., Brinkworth & Turker, 2003). This value would correspond to the point where enough muscle units are recruited such that EMG rises above baseline.
- **Peak latency:** time from stimulus onset until the peak of the waveform is reached. Typically, the peak must occur within some pre-defined window, such as 20-120 ms follow startle (Lang et al., 1990).
- **Onset-to-peak latency:** time computed by subtracting peak latency from onset latency.
- **Peak amplitude and magnitude:** commonly found by subtracting each point in the waveform from the average EMG activity during a prestimulus baseline and then selecting the largest value within a pre-defined window. Amplitude or magnitude expresses the intensity of the muscle contraction associated with the eyeblink response. The major difference is that response magnitude is computed with a zero for trials where a response could not be detected, while the amplitude excludes these trials.
- **Response probability:** total number of detectable eyeblink responses divided by the total number of trials with a startle stimulus. Magnitude is the product of response amplitude and response probability (Berg & Blumenthal, 1986).

Primary acoustic startle circuit

According to Davis et al. (1999), the primary acoustic startle (ASR) pathway in rats comprises only 3 synapses. Following the presentation of an acoustic stimulus, and subsequent activation of the basilar membrane and corresponding hair cells in the organ of corti, cochlear root neurons, located within the cochlear nerve, receive direct input from the cochlea and project axons onto reticulospinal neurons of the nucleus reticularis pontis caudalis (PnC; also called the caudal pontine reticular nucleus). These cells at the PnC then project onto facial, cranial, and spinal motor neurons “and have therefore been regarded as sensorimotor interfaces for the facial and somatic components of the ASR” (Koch, 1999, p. 111). Activating the seventh cranial nerve innervates the orbicularis muscle and other facial musculature responsible for the eyeblink component of the startle reflex (Berg & Balaban, 1999; Davis et al., 1999; Koch, 1999; Koch & Fendt, 2003).

Modification of the Startle Eyeblink Reflex

The startle response is parametrically sensitive to alterations in the internal and external environment (Dawson, Schell, & Böhmelt, 1999; Hoffman & Ison, 1980). Thus, startle modification has been defined as “the change in the amplitude and/or the latency of a startle reaction when the startle-eliciting signal has been preceded or accompanied by another (usually weaker) stimulus” (Hoffman, 1999, p. 1). The *lead stimulus* or *prepulse*, as it is often called, refers to the stimulus that occurs prior to the startle-eliciting signal or pulse, while the time between these two events is known as the *lead interval*.

Startle modification research is generally divided into two primary areas which include short and long lead interval effects in humans (Figure 1-4). Short lead interval effects refer to startle modification by lead stimuli occurring between 0 and 500 to 800 ms and long lead interval effects of approximately greater than 800 ms (Filion et al.,

1998). This chapter is principally concerned with short lead interval startle, thus readers interested in information on long lead effects should see Filion et al. (1998) or Putnam & Vanman (1999) for reviews.

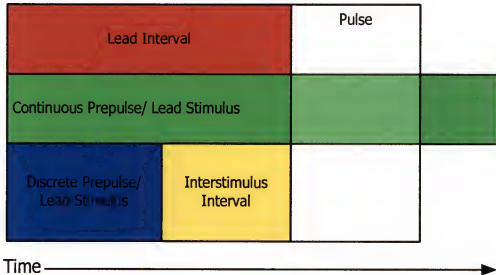


Figure 1-3. Common terms used in startle modification research. Two major types of lead stimuli are shown. Discrete lead stimuli (shown in blue), has an onset and a discrete offset that ends at prior to the appearance of the pulse (tinted white). Continuous lead stimuli (shown in green) appear before the onset of the pulse stimulus, but typically will terminate following the appearance of the pulse signal. The time between the onset of the lead stimulus and the appearance of the pulse is referred to as the lead interval (shown in red). Finally, some researchers will report the interstimulus interval (ISI) for discrete lead stimuli (shown in yellow).

Startle modification effects observed for short lead intervals include amplitude and latency facilitation, as well as amplitude inhibition. Amplitude facilitation and inhibition are often referred to as prepulse or lead interval facilitation (PPF) and prepulse or lead interval inhibition (PPI), respectively. The focus of the next few subsections will be to provide an overview for PPF and PPI at short lead intervals. Latency facilitation effects will not be discussed.

Prepulse Inhibition

Prepulse inhibition (PPI) refers to the relative attenuation in startle reflex magnitude observed when a startling stimulus (i.e., pulse) is closely preceded by a

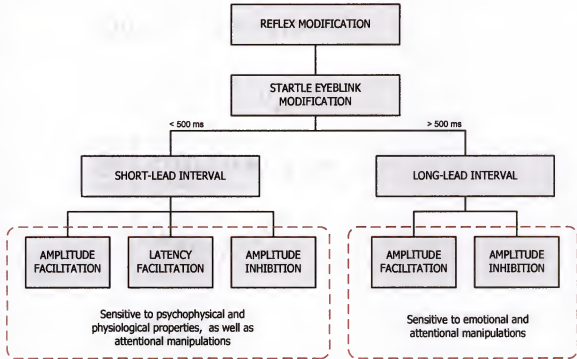


Figure 1-3. Major divisions of startle eyeblink modification paradigms.

transient sensory event (i.e., prepulse or lead stimulus), compared to conditions where the pulse is presented in isolation (Graham, 1975; Hoffman & Ison, 1980). The temporal window for prepulse-pulse pairing to elicit PPI ranges from approximately 30 to 500 ms prior to pulse presentation, with maximum reflex inhibition occurring between 100 to 150 ms for an acoustic prepulse and pulse pair when measured electromyographically underneath the eye (Blumenthal, 1999; Braff, Geyer, & Swerdlow, 2001; Fillion, Dawson, & Schell, 1998). In addition to startle modulation via acoustic-brainstem pathways, PPI appears across the combination of sensory channels, e.g., visual, tactile (Fendt, Li, & Yeomans, 2001; Fillion et al., 1998), making it a powerful tool to study the convergence

of different sensory pathways on common psychological phenomena. PPI is also observed in many infrahuman species, allowing for greater flexibility in experimental protocol and design (Braff et al., 2001). These translational opportunities, taken together with the present understanding for the circuitry and neurochemical substrates involved in the primary startle pathway (Davis, Walker, & Lee, 1999; Koch, 1999; Koch & Fendt, 2003), permits the robust employment of PPI to evaluate the pharmacological effectiveness of chemical compounds used in the treatment of certain neuropsychiatric disorders (Swerdlow & Geyer, 1999; Swerdlow, Geyer, & Braff, 2001).

Three primary hypotheses have been proposed to explain the purpose of the inhibitory effects of a short lead stimulus on startle modification. In his review of short lead startle modification, Blumenthal (1999) suggests,

The phylogenetic ubiquity of short lead interval startle inhibition has led researchers to speculate on the functional significance of this effect. Of course, this phenomenon may have more than one function, so alternative explanations are not necessarily contradictory, exhaustive, or mutually exclusive (p. 64).

Keeping this consideration in mind, the following three explanations will be highlighted:

(1) protection of processing, (2) sensorimotor gating, and (3) automatic and controlled attention.

Protection of processing

Graham (1975) proposed that the inhibitory effects observed when a startle signal is closely preceded by a lead stimulus potentially reflects “a wired-in negative feedback which reduces the distraction produced by reflexes such as startle, and thus protects what has been called pre-attentive stimulus processing” (p. 246). Described by Blumenthal (1999), Graham argued that the presentation of the lead stimulus spawns two automatic processes. The first process operates to identify the prepulse, and the second process

functions to protect the processing of the prepulse from auxiliary stimuli that may interrupt its analysis.

Sensorimotor gating

A problem considered by early attention theorist (e.g., cocktail party problem) was how the brain is able to limit processing to relevant aspects of the environment while ignoring the ubiquity of extraneous information. In their attempts to conceptualize how this may be achieved, the notion of a *filter* was proposed and purportedly functioned to reduce the information-processing burden such that the most relevant aspects of the environment could be selectively processed. Similarly, Braff, and Geyer (1990) propose that PPI is an operational measure of a process called *sensorimotor gating*, “by which excess or trivial stimuli are screened or ‘gated out’ of awareness” (Braff et al., 2001, pp. 234-235). This gating mechanism is hypothesized to relegate the stream of sensory data available for information-processing and may serve to reduce distractibility from irrelevant or erroneous stimuli (Blumenthal, 1999).

Support for a sensorimotor gating view has come from the success of studies using PPI to evaluate neuropsychiatric disorders demarcated by “high distractibility, sensory overload, and reduced habituation” (Blumenthal, 1999, p. 65; Braff et al., 2001). For example, disorders such as schizophrenia, Parkinson’s disease, Huntington’s disease, Tourette’s syndrome, and attention deficit hyperactivity disorder are routinely accompanied by a reduction in PPI compared to control subjects (for review, see Braff et al., 2001). From a clinical perspective, these disorders share the feature of an inability to filter out irrelevant internal or external stimuli, intrusive thoughts, or the inability to suppress undesirable impulses (Dawson et al., 2000; Braff et al., 2001).

Automatic and controlled attentional processing

Early studies of PPI noted that the amount of inhibition was often modulated by a priori knowledge about the lead stimuli. Early studies confirmed that the amount of blink inhibition was greater on trials where the participant knew in advance the location of the lead stimulus, as opposed to trials where the appearance of the lead stimulus was not known (DeIpezzo & Hoffman, 1980; Hackley & Graham, 1983). Demonstration that PPI was also sensitive to task instruction was further demonstrated by both Hackley and Graham (1987) and later by Filion, Dawson, and Schell (1993). In these experiments, task instruction was manipulated such that participants were told to attend to some lead stimuli and to ignore others, or to make judgments about the lead stimulus, such as judging the presentation length of a tone. In all instances, prepulse inhibition was reliably larger on trials where attention was directed to the lead stimulus compared to trials where participants attended away from the lead stimulus or were not given task instruction. Because the majority of these effects occur with lead intervals of approximately 100 – 200 ms, tasks of this nature demonstrate PPI's sensitive to controlled attentional processing.

In another example of attention's modulatory influence on startle, Bradley, Cuthbert, and Lang (1993) presented participants with several pictures representing different emotional contents (i.e., pleasant, neutral, and unpleasant) at various lead intervals. As opposed to a simple tone or visual cue, the pictures served as the lead stimuli in this experiment. Bradley et al. reported a blink inhibition effect for affective content for reflexes elicited early in the viewing period (i.e., 300 ms) compared to neutral content, further demonstrating that startle modification can be reliably modified by attentional parameters. The finding that startle modification occurs in addition to explicit

task instruction also points to an important attribute of startle modification research. That is, short-lead interval blink modification might be interpreted as a measure of motivated attention.

Prepulse Facilitation

Prepulse facilitation (PPF) refers to the relative augmentation in startle reflex magnitude observed when a startling stimulus is preceded by a sensory stimulus. Typically, blink facilitation effects at short-lead intervals are discussed in terms of their physiological implications (Filion et al., 1998). However, as described below, early blink potentiation has been noted to occur at short lead intervals differentially to the semantic content of lead stimuli. In this context, PPF is often interpreted as a function of both attentional and emotional parameters despite the appearance of these stimuli occurring at extremely short lead intervals. PPF effects will be discussed later within the context of attentional bias in relation to anxiety disorders.

Application of Startle Modification to Examine Anxiety

Evidence for the coupling of reduced PPI and certain anxiety disorders has been noted. These data provide evidence that PPI is attenuated or enhanced for anxious subgroups compared to controls for investigations where simple lead stimuli or negatively valenced stimuli serve as prepulses, respectively. For example, using simple lead stimuli, Swerdlow et al. (1993) exposed individuals diagnosed with obsessive-compulsive disorder to four different auditory prepulse intensities (2, 4, 8, or 16 dB above background) and found impaired sensorimotor gating for the 4-8 dB pair. According to the researchers, this finding contrasts PPI effects observed in schizophrenic patients, for example, who display increased sensorimotor deficits with more intense lead stimuli. Grillon and colleagues (1996) found a trend for reduced PPI (120 ms lead

interval) in combat veterans suffering from post-traumatic stress disorder (PTSD) compared to combat veterans without PTSD, but observed significantly attenuated PPI when compared to normal controls. Likewise, Ludewig et al. (2002), exposed patients with clinically diagnosed panic disorder (PD) and controls to 40 ms of 115 dB white noise pulse paired with prepulse stimuli at lead intervals of 30, 60, 120, 240, and 2000 ms. PD patients exhibited significantly reduced PPI at 30, 60, and 240 ms compared to controls. When the PD group was subdivided to determine whether these differences varied as a function of the state or trait dimensions of anxiety, a group by condition interaction emerged, with high trait anxious patients occasioning reduced PPI at the 240 ms condition compared to low trait anxious PD patients.

Application of Startle Modification to Examine Attentional Bias

Aitken, Siddle, & Lipp (1999) first introduced the application of a startle eyeblink modification paradigm to investigate the hypothesized attentional bias effects observed when the primary stimulus is threatening. Aitken et al. presented unselected subjects with 32 words, 16 of which were threat-related, each for 6 s. Following the appearance of each word, the researchers exposed participants to a 50 ms 105 dB white noise burst at 60, 120, 240, or 2,000 ms following word onset. Notably, the researchers observed PPF and PPI at lead intervals of 60 and 240 ms, respectively, and these effects were enhanced for threat words compared to non-threat words. Likewise, in a second experiment, these effects were replicated; however, when participants were selected according to level of trait anxiety, PPF at the 60 ms lead interval was significantly more pronounced for highly trait anxious participants compared to controls. According to Aitken et al., the observation of a differential PPF effect as early as 60 ms would appear to implicate very early semantic processing, some of which may take place in the visual

cortex and analog automatic processing of threat implicated by Öhman and Soares (1994). In a subsequent study with highly anxious children, Waters, Lipp, & Cobham (2000) found supporting evidence for the enhancement of PPI to threat stimuli at both 120 and 240 ms lead intervals.

Limitations

As a whole, cognitive formulations of attentional bias have made significant strides in advancing knowledge about anxiety through theory-driven research and innovative methodology in the past several decades. Despite these advances, there are numerous questions that have not been sufficiently well-addressed, and cannot be verified with the established methodology dominant in this literature. Granted numerous cognitive processes can be isolated from experiments monitoring response time, questions pertaining to the cusp of threat detection and identification, in the context of its broader implications to anxiety, necessitate methodology on a scalable level of analysis that can be implemented to examine information-processing with a finer degree of resolution than can be afforded by examining response time. Further, current accounts of attentional bias often are extremely limited in scope with respect to predictions about how attentional bias might vary with self-reported appraisal of stimuli, differing levels of anxiety, varied perceptual modes of stimuli, length of stimulus presentation, among others.

While robust, the application of startle modification techniques to investigate attentional bias certainly will not address all of the above limitations. However, as demonstrated by Aitken et al. (1999), there are a host of questions relevant to attentional bias and anxiety that may benefit from further employment of startle modification to investigate bias. These questions, in the form of experimental objectives, are presented next.

Experimental Objectives, Description, and Hypotheses

As demonstrated in the above studies, short lead interval startle modification may provide important information regarding the early information-processing sequence of threat content in highly anxious and low anxious individuals. Therefore, the current study exposed high- and low- trait anxious participants to high- and low- arousing unpleasant (threat), and pleasant words, in addition to neutral words. These words served as lead stimuli for an acoustic startle pulse at lead intervals of 40, 50, 60, and 240 ms. The study sought to replicate and extend Aitken et al. finding for a blink facilitation effect to threat words compared to non-threat words at 60 ms for highly trait anxious individuals while also examining three other key objectives.

The first aim of the study was to replicate Aitken et al's findings with a different word set. High (HA) - and low (LA)- trait anxious participants were exposed to high- and low- arousing threat and pleasant words, in addition to neutral words for 500 ms. These words served as the prepulse or lead stimuli. By including both high- and low- arousing words two primary theoretical issues could be examined. As it pertains to threat, the first issue concerns whether highly trait anxious groups are more sensitive in their threshold to threat compared to low trait anxious controls. If this is the case, one would expect that highly trait anxious participants would exhibit greater blink facilitation than low anxious controls to low arousing threat words. Similarly, a between groups effect might also be observed for the onset of blink facilitation for low and high arousing threat content.

A second objective was to determine whether blink facilitation to threat words occurs at latencies prior to 60 ms. Thus, the pulse was presented following word onset at both 40 and 50 ms to determine at what latency do the differential intensity of the word impact blink facilitation, and whether these vary by trait anxiety.

A third objective was to determine whether the blink facilitation observed in Aitken et al's study is specific to threat, or whether it is a function of arousal. It is often the case that pleasant stimuli when included in experiments that aim to address attentional bias to threat, produce similar patterns as threat content. To address this finding, pleasant words, which also varied by stimulus intensity were included.

Hypotheses

The following hypotheses were tested: (1) HA participants will exhibit significantly greater PPF for both the high- and low- arousing threat content compared to neutral content at the 50 and 60 ms lead intervals. (2) The HA group will occasion greater PPF at these lead intervals compared to LA controls for the low threat content only. No differences were expected for highly arousing threat content between groups. (3) Greater PPF was hypothesized for threat relative to pleasant content at the 60 ms lead interval; however, (4) both threat and pleasant content were predicted to occasion greater PPI at 240 ms compared to neutral words, but threat and pleasant content were not hypothesized to differ from each other.

In the next chapter, a review of the attentional bias literature is presented. The chapter includes a comprehensive overview of contemporary perspectives of attentional biases in anxiety, including the prominent theories, methods, and models described in this literature. The chapter begins with a conceptual introduction to attentional bias by providing a platform from which those positions have emerged.

CHAPTER 2

REVIEW OF ATTENTIONAL BIASES LITERATURE: CONCEPTUAL FRAMEWORK, METHODOLOGY, AND THEORETICAL ACCOUNTS

The purpose of this review is to summarize and describe the relevant literature in the area of attentional biases to threat cues in anxiety. Given the breadth of the topic, the emphasis of this exposition will be on information-processing approaches to anxiety, including discussion of common research paradigms, as well as conceptual and computational models consistent with this approach. As a general outline, the following topics will be presented: First, background information related to the study of attention will be provided, including a cursory review of concepts and theoretical perspectives well-known to attention research. Second, the anxiety spectrum disorders will be described, with information pertinent to the various diagnoses of anxiety disorders, including population characteristics, and treatment options being highlighted. Third, evidence suggesting that attentional biases are a central feature of anxiety disorders will be elucidated. Prominent conceptual and computational models, theoretical accounts, as well as commonly employed research paradigms will be addressed. Practical implications and recommendations for future research will also be discussed.

Timing Is Everything

Ethologists and evolutionary biologists have provided numerous examples of defensive adaptations arising from the environmental pressures explained by predation (Curio, 1976; Edmunds, 1974; Endler, 1986). The use of camouflage (blending in with

ones' surroundings), forms of mimicry (closely resembling other noxious animals), chemical defenses (e.g., poisons) sometimes paired with aposematic coloration (the presence of specific markers that signal its foul-taste or poison to other predators) are all commonly employed tactics used by animals to avoid natural predators (Endler, 1986). In addition to these evolutionary engineered defensive adaptations, the ability to rapidly detect and respond to threat offers an added pathway to increasing an animal's proclivity for survival (Öhman, Flykt, & LundQvist, 2000; Öhman & Mineka, 2001, 2003). Indeed, given the conditions of our evolutionary past, an animals' fitness is greatly enhanced through the adaptation of biological systems that facilitate the rapid identification, selection, and deployment of defensive behaviors in the presence of danger (Ledoux, 1996). In this *functional preparedness perspective* (Öhman, 2000), processing efficiency, including detection and the mobilization of neural and peripheral resources to deal with a perceived threat, are instrumental to survival.

Effective defense must be quickly activated. Consequently, there is a premium for early detection of threat. Furthermore, threat stimuli must be detected wherever they occur in the perceptual field, independently of the current direction of attention. Coupled with the bias toward false positives, these factors mean that discovery of threat is better based on quick, superficial, analysis of potential threat stimuli wherever they are than on an effortful, detailed, and complete extraction of the meaning of one particular stimulus (Öhman, 2000, p. 578).

The world in which humans have evolved, however, is a dynamic, information rich environment. At any moment, the brain is inundated by ubiquitous information sources available to it through the various sensory channels. The term *bandwidth* or *throughput*, as used in computing vernacular, expresses the overall physical constraints of a device to process and deliver data. One estimate posits the information-processing capacity of the eye alone at 4.3×10^6 bits/s, with a temporal resolution of about 5 bits/s

per each of the 900,000 fibers in the optic nerve (Jacobson, 1951). The ear, on the other hand, is estimated to be able to process some 8 to 10 Kbits/s, with about 0.33 bits/s per the 30,000 fibers in the auditory nerve (Jacobson, 1950). Whether these values capture the *real* capacity of these modalities remains no more than an interesting figure. Still, it is generally accepted that, as with any information-processing device, the brain is not without its processing limits (Broadbent, 1958).

Notwithstanding processing constraints, the brain must cope with the encumbrances of harmful stimuli that are variably distributed in space and time (Öhman, 2000). A glimpse back to early computers provides an illustration for understanding two problems this poses. The first problem has to do with the need to asynchronously respond to certain classes of external events. For example, early computers were devised solely to perform an algorithm or a series of computations on a fixed data set. The Electronic Numerical Integrator and Computer or ENIAC, considered the first electronic computer, for instance, was used primarily to compute ballistics information (McCartney, 1999). However, the brain, much like modern computers, has had to adapt out of functional necessity to handle the asynchronous nature of the real world. In modern computers, this capability is achieved partly with *interrupt requests* (IRQ), which operate to instruct the central processing unit (CPU) to make what is called a *context-switch*. A context-switch refers to the immediate storing and restoring of whatever process is being executed by the CPU. When pressing a key on the keyboard, the printer is out of paper, or some system device needs “attention” by the CPU, an IRQ is asserted. Similarly, the brain must also cope with the asynchronous nature of the real world, interrupting ongoing operations to deal with an immediate need. The unexpected course of an incoming curveball, the near

and sudden crossing of a snake along a trail, or a loud sound heard from behind, all represent situations with which the brain and nervous system must manage at any moment in time.

A second problem, related to the first, has to do with organizing and setting processing priorities when important events occur. Again, in computing, a *process* refers to a collection of *threads* or *tasks* that need to be executed by the CPU. The term *time-slice multithreading*, also called *superthreading*, allows a modern CPUs to execute multiple threads concurrently, hence the advantage of running multithreaded applications on dual-processing, dual-core, or computer clusters leads to faster overall execution (Stokes, 2002)². In some programming languages, processing priority or *scheduling* of a given thread can be adjusted to decrease the latency in which it is executed. Attention theorists and several attentional bias models of anxiety alike, both regard the ability to *selectively tag* information for processing priority central to handling time-critical operations such as responding to threat. When a predator appears in the visual field, for instance, it is crucial that certain processes are prioritized for evaluation to best ensure chances of survival.

In accord with the necessities of responding to environmental contingencies, the brain is able to permit goal-directed appetitive behaviors with the ability to rapidly engage defense countermeasures in the presence of danger. In the *Evaluative Space Model* (ESM; see Figure 2-1)³, for example, Cacioppo and colleagues (1994; 1999) postulate how an organism's affect system may be organized to achieve a dynamic

² Both LabVIEW and Java are examples of multithreaded programming languages.

³ A screenshot of the program created to evaluate how changing the input parameters alter bivariate evaluative space is available in the appendix and can be downloaded at <http://hhp.ufl.edu/ess/mblab>.

balance between appetite and defense. As depicted, the ESM suggests that positive and negative information initiates the activation of two functionally separate evaluative processors (i.e., positivity and negativity). Together, the summation of these processors equate to a net predisposition to move toward or away from a given stimulus. Because these processors are relatively distinct, each has the flexibility for the local environment to shape its activation function (Cacioppo & Berntson, 1999). In the top-right corner of the figure, each functions' activation pattern is characterized. At a net predisposition of zero, a small offset toward positivity can be noticed. Additionally, as activation increases for either function, it can be seen that the slope for negativity increases faster than for positivity. Together, these functions express what has been called a *positive offset* and *negativity bias*. According to Cacioppo & Bernston (1999),

Exploratory behavior can provide useful information about an organism's environment, but exploration can also place an organism in harm's way. Because it is more difficult to reverse the consequences of an injurious or fatal assault than an opportunity unpursued, the process of natural selection may also have sculpted a propensity to react more strongly to negative than positive stimuli (p.136).

As the Evaluative Space model suggests, there is a fundamental orientation to rapidly shift into defense at lower levels of activation than for positivity. This predisposition, however, can be shaped by the local environment in the interest of survival.

As part of the architectural attributes of the affect system, the mobilization of neural and peripheral resources in preparation for defense (*viz.*, fight or flight) increases an organisms' aptitude for survival. For the acoustic startle in rats, a reflex is produced in a mere 8 ms when measured electromyographically from the rat's hindleg (Lang, Davis, & Öhman, 2000). While defensive reflexes are one such means to provide an organism

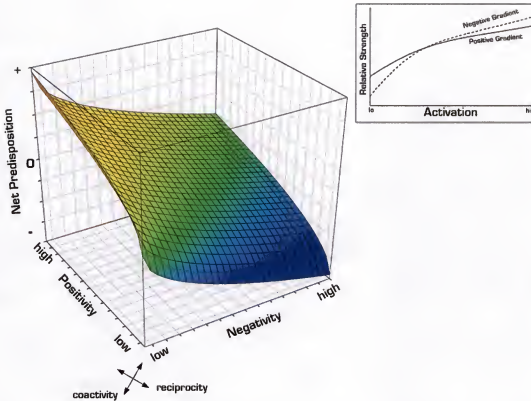


Figure 2-1. The Evaluative Space Model (depicted) is useful to illustrate how various local conditions may influence the dispositional attributes of an organism. The model depicts two distinct evaluative processes, one representing positivity (approach), and the other negativity (avoidance). The sensitivity of these motivational parameters at differing levels of activation alter the gradient of approach and avoidance, respectively. By manipulating the strength of different input parameters one could model the response characteristics of motivational tendencies shaped through diverse environmental contingencies. For example, the figure above would suggest a small offset toward positivity (i.e., positive offset), while also suggesting a rapid shift from positivity to negativity at low levels of activation (i.e., negativity bias). If the above depiction represents an organisms' evaluative space that is theoretically 'normal', one might also think about the response gradient in terms of a specific psychopathology.

with a quick stereotyped response in circumstances where danger is imminent, it is the preemptive "tuning" of these reflexes that aid to rapidly counteract environmental hazards. More generally, research employing startle probe methodology with humans has repeatedly demonstrated that elicitation of the startle reflex in a context that provokes a defensive orientation leads to an exaggerated startle response (Bradley, Cuthbert, &

Lang, 1990; Cuthbert, Bradley, & Lang, 1996; Lang et al., 1990; Schupp, Cuthbert, Bradley, Birbaumer, & Lang, 1997; Vrana, Spence, & Lang, 1988).

Augmented startle, in this arrangement, is illustrative of defensive motivational activation. Along with priming reflexes in preparation for defense, other physiological response patterns exhibit a different path as activation increases (Bradley & Lang, 2000).

Accordingly, the *Defense Cascade Model* (Lang, Bradley, & Cuthbert, 1997) as seen in Figure 2-2, depicts how physiological output systems differentially change with increasing defensive activation. The model spans the following three broad defensive behavioral stages that change according to the proximity of a natural predator (Bradley & Lang, 2000): (1) *Pre-encounter*, preparatory behavior occurring in the context of foraging where a predator has been previously encountered, (2) *Post-encounter*, referring to behavioral changes in response to the detection of a distant predator, and (3) *Circa-strike*, defensive behaviors in response to imminent threat. In this figure, the response from three physiological response systems are shown, with amplitude displayed on the ordinate and emotional intensity or activation represented on the abscissa. The appearance of any novel stimulus elicits the orienting of attention for further stimulus elaboration at lower levels of activation. This is reflected by the progressive decrease in cardiac activity, and the relative inhibition of the startle reflex during behavioral freezing. Thus, at early stages of stimulus processing, there is relatively little difference whether the stimulus is threatening or not and activation is representative of *motivated attention* (Bradley & Lang, 2000). However, as defensive activation initiates, preparation for possible fight or flight corresponds with increases in skin conductance level (SCL), startle potentiation, and sympathetic increases in cardiac output, providing metabolic support if an overt

action manifests. Although the vacillation amongst the various stages may occur over different time scales, the transition from calm to intense activation may transpire with great rapidity. For example, when viewing pictures of their own feared object, phobics show startle potentiation as early as 300 ms in comparison to control pictures, while normal participants do not display this difference until around 800 ms (Globisch, Hamm, Esteves, & Öhman, 1999).

Specialized circuits for processing threat-related information may also offer distinct advantages in the interest of promoting survival. Accordingly, Ledoux (1995) has described a “quick and dirty” subcortical pathway that allows for very rapid, but crude, analysis of stimulus features from the incoming visual stream (Ledoux, 1995, 1996; see also Shi & Davis, 2001). This route, dubbed the “low-road”, involves direct thalamo-amygdala pathways allowing for a cursory but rapid analysis of visual objects passing from the retina into the fear centers of the brain. Likewise, Öhman, in his *Model of Fear Activation* (1993), has alluded to a hard-wired feature detection system that preferentially identifies evolutionary prepared stimuli (e.g., snakes, spiders). This view of emotion proposes that feature detectors evaluate stimuli at a very crude level of analysis and can subconsciously trigger ancillary attentional mechanisms to further evaluate stimulus significance (Öhman, 1999), and will be further elaborated in a later section.

As one might infer, the theme thus far presumes that the ability to respond to threat is the culmination of many systems that have evolved to counteract predation. These limited-capacity systems operate in an environment that is inundated with information, some of which signal danger and demand information-processing priority to quickly deal with a potentially imminent threat. It should be no surprise then that the chain of early emotional

processing has been a core interest for many researchers studying the fear system, and more generally, dysfunctions of the fear system as they relate to psychopathology.

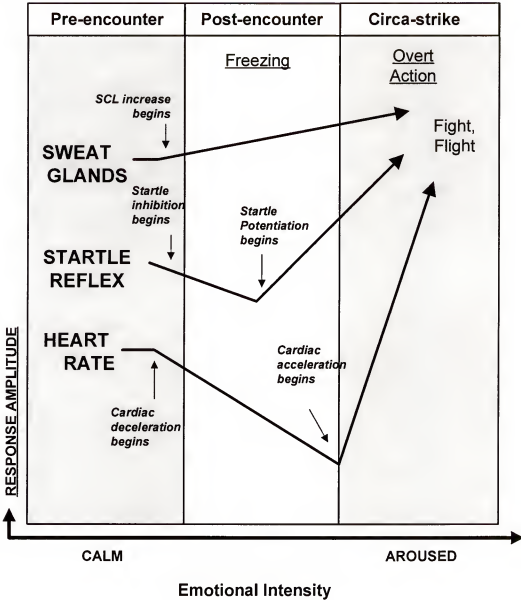


Figure 2-2. The Defense Cascade Model by Lang, Bradley, & Cuthbert (1997). The model depicts how different physiological systems are differentially prepared as defensive activation increases. In the context of startle modification, the model predicts different reflex activation depending on the stage of defensive activation. In the early pre-encounter stage, blink modification to an potentially threatening stimulus, for example, results in startle inhibition, whereas, once the defensive activation is primed (i.e., the post-encounter stage) elicitation of the reflex results in a facilitated response. Once overt action has occurred, blink potentiation no longer occurs.

The nature of early attentional biases for negative information has been the source of theoretical importance in many cognitive accounts of anxiety. Indeed, while threat detection and the readying of defensive behavior are crucial elements of species survival, biases in information-processing, particularly in the automation of attention to threat cues, are thought to be tightly coupled with the etiology and perpetuation of anxiety disorders (Beck & Emery, 1985). In recent years, cognitive formulations of anxiety have made much progress in establishing both the theoretical and methodological foundations for understanding the nature of attention in anxiety and related disorders. Still, debates surround whether anxiety disorders are demarcated exclusively by (1) the attentional capture of threat cues, (2) the delayed disengagement from threat cues once a threat has been detected, or (3) a combination of both. Before these and other issues are specifically discussed, the next section will first introduce information germane to the anxiety spectrum disorders. General information related to the differential diagnoses of anxiety disorders, prevalence rates, and treatment options are briefly addressed.

Overview of Attention

Selective Attention

Given that most every treatise on attention begins with a quote by William James, this review does not deter from this tradition:

Everyone knows what attention is. It is the taking possession by the mind in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought...It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatterbrained state. (1890, p. 403).

At the core of James' definition of attention is a tightly knit connection with consciousness (Abernethy, 2000). Some theories, however, allude to the nature of automatic or preattentive processing, operating below consciousness, as fundamental to

cognition and behavior (Öhman & Soares, 1993, 1994; Zajonc, 1980). Nevertheless, James' definition of attention advances the notion that processing certain information limits processing of competing information, which is the defining feature of *selective attention*.

It's a party

The *Cocktail Party* phenomenon, introduced by Cherry (1953), refers to an early working metaphor used to frame issues related to selective attention. Cherry addressed how a given partygoer is able to select one stream of dialogue amid other conversations (or, in turn, what verbal content of other conversations might be attended to), and lends itself as an organizing framework for early attention research within the auditory modality.

Early filter models of selective attention

A central tenet to early models of attention is the notion that humans have a finite ability to process information. Adhering to the cognitive metaphor of information-processing, the execution of data through a system is conceptually permitted to operate in a *serial* or *parallel* fashion. Serial processing refers to operations that occur exclusive of other tasks, while parallel refers to a mode of processing in which one stage of information-processing can occur concurrently with other operation stages. Because it generally assumed that critical operations can only execute serially, the point of debate for filter models is the determination at which stage parallel execution switches into serial processing (Pashler & Johnston, 1998). The point of the transition from parallel to serial processing is referred to as a *bottleneck*.

Broadbent (1958; see Figure 2-3) postulated that a stimulus filter is located in the early stages of processing. As depicted in the figure, information enters the brain through

the various sensory channels, stored momentarily in a short-term data store (buffer), and unselected information is subsequently filtered from further processing based on physical stimulus characteristics (e.g., sound location or pitch). Broadbent's resulting filter model was assembled from his work using dichotic listening tasks. In the prototypical task, two auditory messages are simultaneously presented separately to each ear and subjects are told to listen and repeat one message (i.e., shadowing) while ignoring the other.

Generally, findings indicated that semantic information of unattended channels was not acquired, but that physical/structural information (e.g., whether the voice was male or female) was retained (Broadbent, 1958). By placing the filter early in the chain of processing, Broadbent's solution for the cocktail party problem enabled an imaginary partygoer to selectively weed out background conversations from the distinct physical properties of the currently attended dialogue. In progression through the bottleneck, unfiltered information is subsequently allowed more elaborative processing.

Moray (1959) and Treisman (1960), however, both provided evidence that Broadbent's filter model could not account for the finding that messages not sharing the same stimulus properties could pass through the filter. Again, using the dichotic listening task, Moray found that if a command, presented to the unattended channel, preceded an affectively charged word, then a participant's attention would shift to the unattended channel. Similarly, Treisman demonstrated that participants would continue to shadow a message for a few seconds when it switched from the attended channel to the unattended channel. Further support provided by Corteen and Dunn (1974) found that when words previously paired with shock were presented to an unattended channel, a subsequent galvanic skin (GSR) change was elicited. Additionally, an increase in GSR was

demonstrated for synonyms of the previously conditioned words when presented to the unattended channel. In all cases, evidence indicated that the selection of one channel over another involves more than stimulus features alone, and that unattended information was being processed in more detail than Broadbent's filter model would suggest.

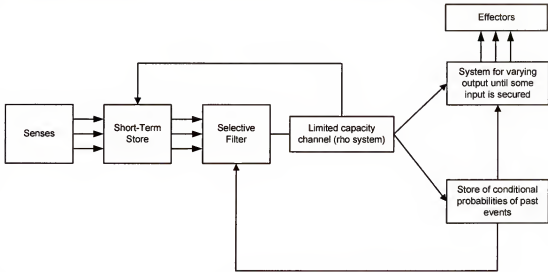


Figure 2-3. Broadbent' information-processing model of selective attention.

Realizing that placing the bottleneck early in the information-processing chain could not accommodate these findings, Treisman (1969) reconceptualized Broadbent's filter into a *selective attenuator*. This attenuator is essentially a threshold detector, whereby its function is to reduce information from unattended sources, but to register salient information even when originating from an unattended channel. In this view, unattended information could surpass cursory stimulus analysis and be further processed for semantic content if its activation exceeded a specified threshold. Though some researchers were unconvinced with Treisman's proposal, citing the complexity of processing operations needed to attenuate an incoming message at multiple stages (Norman, 1969), others offered additional evidence that unattended information could be processed for semantic content, solidifying the perspective that the filter should be

located in the latter information-processing stages (e.g., Deutsch & Deutsch, 1963).

Bridging both late selection and the attenuation features of Treisman's model, *Norman's Pertinence model* (1968; see Figure 2-4) allows all incoming signals to be processed to determine their stored representation in memory (The storage system). As an initial message is decoded and subsequently selected, information is then fed back to a pertinence system, which concurrently activates stored representations in memory. Together, the activation of both the incoming information arriving from the sensory system and additional activation from the pertinence system summates to the selection of a particular item for more detailed processing (the shaded cluster).

Further modifications of Broadbent's initial filtering concept introduced a high level of ambiguity into the filter metaphor. Norman's (1968) proposal of a moving bottleneck, for instance, was directly aimed at accounting for evidence demonstrating that unattended information could be processed at later stages, while limiting the amount of information passing onto subsequent stages. Accordingly, at each stage of information-processing, a priority value was proposed to be assigned to items being processed. Information receiving low values would thereby be blocked from further processing, while information receiving high values could proceed to subsequent processing stages. Throughout this process, an item may lose its high priority rating and be blocked from further processing. The notion of tagging information for processing priority in addition to the concept of processing threshold, as will be seen, are both ideas implemented in models of the attentional biases purported to underlie anxiety.

The relocation of the bottleneck at later processing stages, however, presented its own conceptual problems. Mostly, the concept of an information filter was introduced to

be in accord with perspectives of limited capacity systems. Theoretically, if all incoming sensory information is being processed to a great degree, then the original conceptualization of filter is rendered irrelevant (Hirst, 1986). Hirst summarizes,

Norman is asserting that there is no point at which the limitations of the system imposes itself. Rather, the system is constantly working to limit the demands placed on it. There is no bottleneck, then; just a limited processing capacity that the organism must constantly struggle to stay within. This concept of 'limited resources' was to play a central role in the theory of divided attention that Norman helped develop (1986, p. 113).

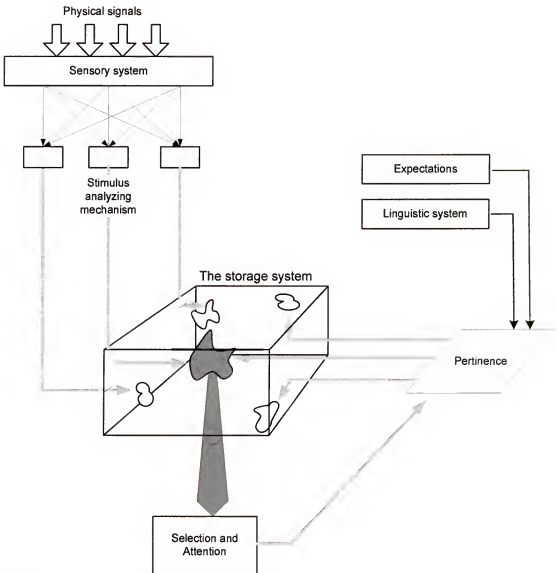


Figure 2-4. Norman's pertinence model of attentional selection.

Resource Theories

Resource theories developed in the spirit of early perspectives that humans have a limited capacity to process information. This limitation is particularly expressed in situations where attention is divided among multiple tasks. For example, dribbling a basketball or jogging a few meters are not thought to be extremely difficult tasks by themselves; however, the pairing these two tasks together can be overwhelming for beginners. The application of filter theories to dual-task situations followed the logic that, although many aspects of both tasks could occur in parallel, the critical mental operations of either task happen sequentially (Pashler & Johnston, 1998). Within this context, the nature of resources or capacity models of attention evolved. Some researchers posited that the ability to perform a given task is conceptually related to the amount of *resources* available to meet the demands of that task (Kahneman, 1973; Norman & Bobrow, 1975). This conjecture does not preclude multiple critical mental operations from occurring concurrently so long as enough resources are available to complete each cognitive action. Resources, in this view, can be conceptualized as a mental fuel that is exhaustible, thereby leading to economic metaphors such as “paying” attention and “investing” effort in tasks.

Single resource views

Two lines of thought are favored by advocates of resource theories. On the one hand, early resource proponents advanced a single limited capacity resource pool that assists in a diversity of mental operations (Kahneman, 1973; Norman & Bobrow, 1975). Kahneman (see Figure 2-5) for example, argued that performance on a task or a group of tasks depended on the amount of resources allocated to each activity.

As illustrated in the figure, a single pool of resources is represented (at the top). Although the gross capacity of this pool is fixed, the net capacity of this pool is largely a product of arousal. At center, a resource allocation mechanism determines how much of investment to allot to each of a number of processing activities (at bottom).

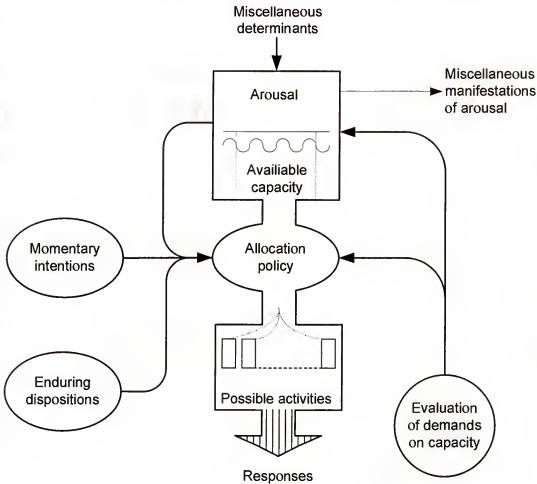


Figure 2-5. Kahneman's resource model of attention.

Such factors as momentary intentions, enduring dispositions, and the determination of capacity demands influenced the allocation of resources for a given task. According to Wickens, 1992, these types of single-pool models can be described loosely as $P = R / D$, where P equals performance, R represents resource allocation, and D stands for task

demand. If resource allocation increases while task demand remains constant, then an increase in performance should result.

Norman and Bobrow (1975) later refined the single-pool perspective by differentiating between performance limitations due to available information (data-limited) and the amount of resources dedicated (resource-limited) to a task. This distinction is specified in the performance-resource function elucidated by Norman and Bobrow (1975) and is illustrated in Figure 2-6.

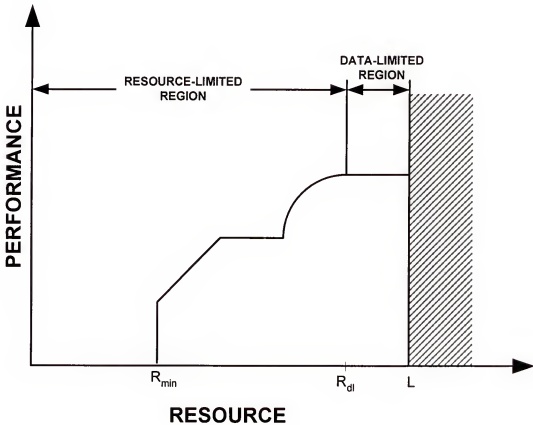


Figure 2-6. Hypothetical POC curve.

As depicted, a performance function is plotted, with performance shown on the ordinate and the number of resources represented on the abscissa. On the abscissa, the minimum amount of resources to complete a task is represented by R_{min} , the point at

which resources become data-limited is shown as R_{DL} , and the maximum upper resource limit is shown as L . From the plot, two key features about Norman and Bobrow's conception of a resource can be noted. First, there are points at which a net increase in resources offers no improvement in performance, and second, that resource capacity is finite.

Multiple-resource views

In contrast to the view that the brain contains only a single pool of resources, multiple resource theories argue for many independent limited capacity pools that could operate independently (Navon & Gopher, 1979; Wickens, 1984; 2002). Multiple resource theories grew to accommodate data suggesting that performance of a task in one modality (e.g., a visual task) is virtually unaffected by the addition of a task occupying another modality (e.g., an auditory task).

In the most widely recognized version of multiple resource theory (see Figure 2-7; revised from 1984 model), Wickens (2002) describes a four-dimensional resource model comprised of *processing stages* (perception, cognition, responding), *perceptual modalities* (visual, spatial), *visual channels* (focal, ambient), and *processing codes* (spatial, verbal). This revised version of multiple resource theory evolved from an earlier three-dimensional account (see Wickens, 1984 of a detailed description of each of these dimensions), which did not include a dimension for different visual channels (i.e., focal, ambient).

Both anecdotal (e.g., reading a book while walking down a hallway) and experimental (e.g., the elucidation of brain structures specific to each type) evidence makes a strong case for disparate resources between these two types of visual processing (Wickens, 2002). Focal vision corresponds to foveal vision for detailed visual processing,

while ambient vision refers to peripheral vision. In both variations, Wickens (2002) argues that each element equates to discrete physiological mechanisms establishing its resource independence from other elements. That is, the ability to drive and listen to the radio, read and listen to music, speak and turn on the windshield wipers, can all co-occur to some extent, because performance of each relies upon different resource streams. Critics of multiple resource theory, however, argue that the theory is not able to be falsified and that the flexibility afforded by the concept of multiple resources is easily adept to account for new data simply by adding another dimension (Kantowitz, 1987).

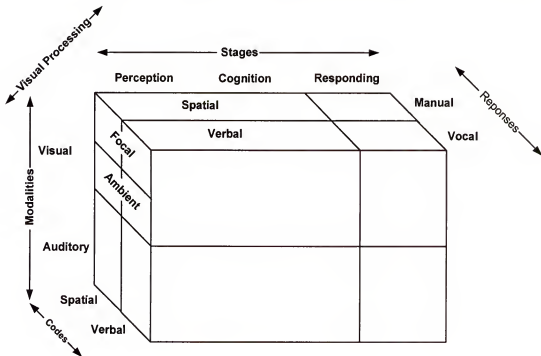


Figure 2-7. A three-dimensional illustration of Wickens' Multiple Resource Theory.

Visual attention

Evidence for early accounts of selective attention originated from paradigms that evaluated language via the auditory system. However, the *physical/semantic* distinction, dominating early debates on the placement of the postulated bottleneck, did not readily

apply to attention in the context of the visual system (Driver, 2001). Still, the notion of limited capacity remained fundamental to the study of visual attention (Wolfe, 2000). The study of visual attention is compartmentalized into two primary interacting domains. The first research area corresponds to evaluating *how* visual attention is controlled, and the second involves determining *where* visual attention is directed (Lauwereyns, 1998). The *how* of visual attention involves the examination of exogenous (*bottom-up, stimulus-driven*) or endogenous (*top-down, goal directed*) control, and the *where* refers to space-based or object-based visual information processing.

The term *exogenous control*, when applied to visual attention, refers to some attribute of a visual stimulus (i.e., stimulus driven) which elicits an attentional shift to the stimulus from an observer. For example, the onset of a low-fuel indicator may evoke an exogenous attentional shift to the dashboard indicator. On the other hand, *endogenous control* refers to the intentional allocation (i.e., goal-directed) of visual attention by an observer to a stimulus. For instance, a driver becomes aware that fuel is low and therefore repeatedly directs attention to the low-fuel indicator. To explain where visual attention is allocated, *space-based theories* of visual attention posit that attention is directed to discrete spatial locations in the visual environment, while *object-based theories* argue that visual attention is directed to processing preattentive perceptual objects (Egeth & Yantis, 1997).

Posner (1980) introduced two additional terms pertinent to the control of visual attention. In top-down or bottom-up fashion, an *overt* attentional shift refers to an observer altering the position of attention by moving their eyes to the to-be-attended location, while a *covert* attentional shift refers to a shift in visual attention in absence of

an obvious eye-movement. To illustrate the experimental problem this poses, Figure 2-8 shows two pictures with a participant's scan path superimposed. The red lines on each picture represent *saccades*, and the blue circles correspond to *fixations*. A saccade is ballistic, intermittent eye-movement shift between fixations, while a fixation is a transient absence of an apparent eye-movement (~100 ms). Because eye movement registration technologies (e.g., corneal reflection, electro-oculogram) provide only an index of overt visual attention shifts, and although in many cases it may be a safe assumption to parallel visual attention and gaze characteristics (e.g., Henderson, 2003), covert shifts that occur in the absence of eye movements cannot be detected with current instrumentation. As such, inferring attentional shifts through eye movement recording and then drawing conclusions specifying where in the visual environment attention is directed is potentially problematic. That being said, with very few exceptions, a saccadic eye movement to a particular stimulus is either preceded by or mandates a shift in visual attentional allocation (e.g., Hornak, 1992; Robinson & Kertzman, 1995; Walker & Findlay, 1996; Zelinsky, Rao, Hayhoe, & Ballard, 1997). However, once an object has been fixated, it is both conceivable, and in many situations, advantageous, to decouple the line of attention from line of sight (i.e., shift attention without shifting where one is looking) (e.g., Stelmach, Campsall, & Hardman, 1997). As such, the number of fixations to a target provides one index (i.e., the number of attentional shifts made to a particular scene or stimulus) of attentional allocation. However, neither fixation frequency nor any other gaze measure is capable of providing an index of attentional maintenance once a particular stimulus or aspect of a scene has been fixated upon.

Given these conceptual distinctions, a variety of notable metaphors, paradigms, and theories of visual attention have shaped our notion of how information is extracted from the visual environment.

Metaphors of Visual Attention

The *spotlight metaphor of visual attention (SMVA)* explains how an observer may select aspects of the visual environment (Egeth & Yantis, 1997; Posner, 1980).

According to the metaphor, a *beam of attention* is directed to a specific area of the visual field, which, in turn, enhances the processing of information within that field. While on the surface, the metaphor appears to provide a simplistic syllogism to understand visual selection, many aspects of the metaphor have produced a great deal of debate (Fernandez-Duque & Johnson, 1999), such as: *How large is the spotlight? Is there more than one spotlight? Does the spotlight move in analog or digital fashion and how fast can it be moved from one place to another? Is there an executive mechanism that controls the spotlight?*

Stemming from some of these issues, the *zoom-lens metaphor* first described by Eriksen and James (1986) closely parallels the spotlight metaphor, but as an addendum, argues that the resolution of the attended area is not necessarily fixed but can become more or less detailed by increasing or decreasing the size of the beam. Finally, LaBerge and Brown (1989) abandoned the notion of a single unitary concept of visual attention and instead proposed a *gradient metaphor* of visual selection. In this view, attention can be divided into multiple regions in the visual field. In contrast to repositioning the attentional beam or altering the beam's resolution, "in the gradient metaphor, the amount of resources in a certain



Figure 2-8. Shows scan path and fixations for two images by a single participant.

part of the attention field is a function of its distance from the attention peak and the slope of the gradient (Fernandez-Duque & Johnson, 1999, p. 94).

Visual Attention Paradigms and Feature Integration Theory

Within the voluminous literature of visual attention, a host of influential paradigms and their modifications have subsequently shaped the varied theoretical positions of attentional biases in the anxiety disorders. It is these paradigms that are the focus of this subsection; however, they will be discussed here as they strictly relate to basic visual attention, and will be revisited within the context of their use of attentional bias in anxiety disorders later.

A popular technique for investigating the spectrum of issues pertaining to visual attention and perception has been the *visual search* paradigm. Prototypical visual search tasks will typically require a participant to locate a *target* element among several *distractor* elements. The number of elements a participant is shown at any one time is commonly referred to as the *array size* or *display size*. The target may be defined based upon a specific feature (e.g., color, size, shape, orientation) or a *conjunction* of more than one feature (e.g., a blue square). In the context of exogenous attentional control, Egeth and Yantis (1997) refer to rapid visual onsets and *singletons*, which are targets that differ in one or more visual attributes from distractor elements, as the two major categories of stimuli that may automatically capture attention (i.e., bottom-up control).

Numerous examples illustrate the efficiency of the visual system at finding singletons (e.g., Treisman & Gormican, 1988) as well as numerous examples of caveats to this generalization (e.g., Jonides & Yantis, 1988). Figure 2-9 demonstrates a simple example. First, find the blue triangle in the top-left panel, then the top-right panel. What one may notice is the virtually effortless appearance of the blue triangle in the top

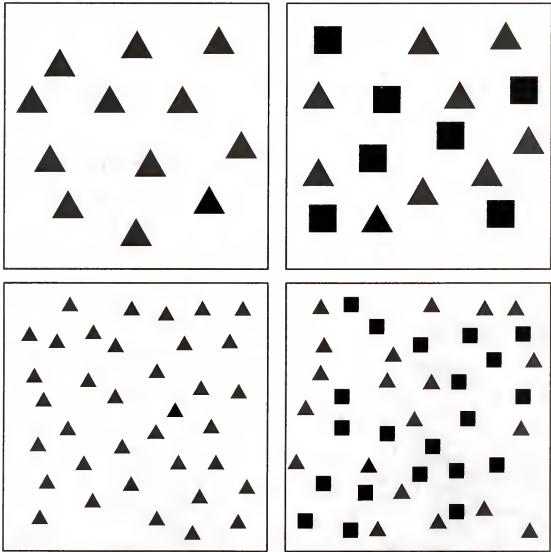


Figure 2-9. Example of simple visual search task.

left-panel and while fast, a slightly delayed time to locate the blue triangle in the top right-panel. Similar to its parlance in information-processing, the term parallel search or “pop-out” is often applied in this context to suggest the ability to evaluate multiple items simultaneously, even when the array size increases. Serial search, on the other hand, refers to the need to evaluate each item individually. According to Treisman and Souter (1985), a search slope, which is calculated by dividing the average increase in response time by the total items in the array, should not exceed an increase of less than 5 ms per

search item to be considered a parallel search. Again looking at Figure 10 at the lower-left panel, despite the apparent increase in array size, finding the blue triangle is still quite efficient, whereas the task of locating the blue triangle in the right-panel now takes relatively more time than the stimulus set above (top-right). Evidence presented by both Pashler (1988) and Theeuwes (1991) support the notion that some singletons capture attention demonstrated by including a task-irrelevant color distractor element(s) in a search task. The idea is that on trials where the singleton distractor items are present, the time to locate the target should be longer than when the items are not present. To address how this might occur, feature integration theory was introduced.

Feature-Integration Theory

Feature-Integration Theory (FIT; Treisman & Gelade, 1980) argues that the purpose of visual attention is to *bind* features together in the visual environment (see Figure 2-10). A *feature* refers to a primitive property of a visual stimulus such as color, luminosity, or curvature, which are each discretely coded by individual visual areas. FIT assumes that two major classes of events occur to permit visual recognition and perception. First, preattentive feature detectors parse incoming visual information into separate *feature maps*. These maps operate to differentially code the existence of specific features such as shape and size, but do not operate to provide spatial information about each feature (Quinlan, 2003). That is, the detection of a particular feature or the knowledge that a particular feature exists, is separate from the process that indicates where in the visual field the feature is located. In a second processing stage, spatial information is extracted by first combining features to form a *master map of locations*. The master map of location provides information where individual features are located,

but needs focused attention to determine which features occur together (Treisman & Gormican, 1988).

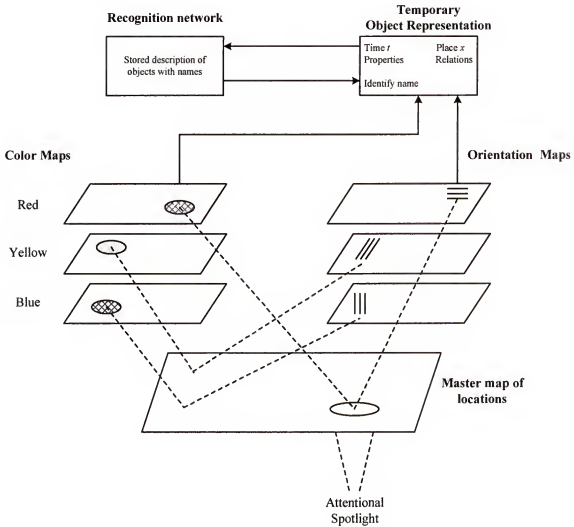


Figure 2-10. Feature-integration model by Treisman & Gormican (1988).

Pop-out in visual search is postulated to arise from the activity produced by the unique feature of the target item against distractors, and does not require attention.

However, when a target is defined by a conjunction of features, the binding of these features requires attention. Referring back to Figure 2-9, in the upper- and lower- left panels, the target only differed on one dimension (i.e., color), and for the upper- and lower- right panels the target was defined based on both its shape and color, thus each

item must be attended until found. Treisman and Schmidt (1982) specify three ways in which the integration of features occur: (1) through focused attention via the attentional spotlight mentioned above (Posner, 1980), (2) through prediction of an object's features, and (3) through the random assemblage of features because of a lack of focused attention or expectation, otherwise called, *illusory conjunctions* (Treisman & Schmidt, 1982).

According to Quinlan (2003), a few problems with FIT led to modifications of the original theory. One major problem, was the finding that certain conjunctive targets pop-out, thereby contradicting predictions of FIT (e.g., McLeod, Driver, & Crisp, 1988). Nevertheless, given the scope of these and other issues, the interested reader is referred to Quinlan (2003) for a comprehensive review of FIT.

Location cueing paradigms

Location cueing paradigms refer to a subclass of visual search paradigms where the main emphasis of the task is to determine the onset or the spatial position of a target as opposed to simply locating a target among distractors. The cost/benefit paradigm, introduced by Posner, Nissen, and Ogden (1978), is a type of location cueing task where the emphasis is to evaluate both exogenous and endogenous components of visual attention. An individual's *set*, or as it is later called in Posner's parlance (1980), *orienting response*, refers to the redirecting of attention to the source of an input signal. Posner et al. argue that activation of a primary pathway produces *benefits* for additional items sharing this pathway, whereas *costs* occur because of the need to shift attention from a primary- to an auxiliary pathway. Given that attention is putatively needed to produce an overt response, Posner et al. argue that costs and benefits of attending can be assessed through performance indices (e.g., reaction time).

In the first of 4 experiments (Figure 2-11) to examine the attentional chronometry and attributes of costs and benefits, Posner et al. (1978) asked participants to keep their eyes centrally fixated throughout the experiment (covert attention only) and to press a key corresponding to the spatial location of an “X” appearing to the left or right of a central point. Figure 2-12 illustrates the original cost/benefit paradigm. Second, one of three warning cues were displayed centrally prior to the appearance of the target at 0, 50, 150, 500, 1000 ms. For a cross cue (+), the target had an equally likely chance of appearing on the left or right. Alternatively, for arrow cues (\rightarrow or \leftarrow), two possibilities could occur. On *invalid trials*, the target was presented in a spatial location not correctly indicated by the cue, and on *valid trials*, the target was presented in a spatial location consistent with the direction of the cue. In this context, Posner and colleagues evaluated the attentional benefits associated with having an a priori knowledge of the spatial position of the target (neutral-valid), and the attentional costs of attending to incorrect spatial locations (invalid-neutral). The extent of attentional costs and benefits (as measured by RT differences) were referenced to uncued trials.

Results showed that the cost of first attending to an invalid location and, in contrast, the benefit of attending to a valid location, is evident when a warning signal precedes the target as early as 50 ms. This trend accumulates over a period of approximately 150 ms, where the number of errors for invalidly cued trials asymptote. Although a warning cue produced significant benefits as to the location of the target stimulus, a follow-up and extension by Posner, Snyder, and Davidson (1980; Experiment 2) modified the task to determine whether benefits could be realized either by providing spatial information about the target or by improving the target’s ability to be detected.

Again, information pertaining to the target's location led to significant improvements in performance, while information pertaining to the target's form offered no performance advantage.

Finally, to examine the spatial informativeness of the warning cue, Posner (1980) found that participants were faster at responding to a target when preceded by a peripheral cue as opposed to a centrally presented directional cue to a spatial location where a target may appear. Taken together, these studies provide a foundational framework for certain probe detection studies used to investigate attentional bias in anxiety, to be discussed later.

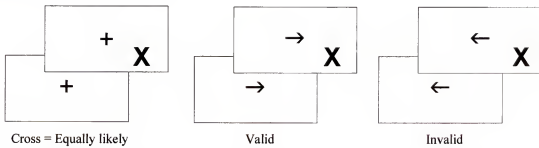


Figure 2-11. Original cost/benefit paradigm used in Posner et al. (1978).

Summary

Much like anxiety, attention is not a single unitary concept, but rather is a term that describes a variety of interrelated phenomena. As will become evident, attentional processes form critical mechanistic explanations for numerous cognitive accounts of anxiety. Concepts such as stimulus detection, selection, modes of processing (top-down/bottom-up), resources, and time-critical processing of information within the environment are themes pervasive throughout the perspectives to be reviewed. Additionally, virtually all of the paradigms used to examine bias in anxiety have arisen from studies investigating basic properties of attention. Together, the study of the

attentional biases in anxiety has grown into a monolithic area of research. What follows is an attempt to summarize some of the current views on the cognitive study of attentional biases in anxiety.

Review of Cognitive Accounts of Anxiety: Methodological Considerations

Cognitive accounts of anxiety suggest that information-processing biases to negative information play a crucial role in the etiology and maintenance of anxious states (Mogg & Bradley, 1999). Influential theories by Beck (Beck, 1976; Beck & Clark, 1997), and Bower (1981) similarly contend that mood-congruent biases affect all aspects of information-processing. As it specifically relates to anxiety, the extant data collectively favors a streamlined perspective that attentional biases to negative information are a hallmark feature of anxiety disorders (Williams et al., 1988; Mogg & Bradley, 1998). Despite this unified perspective, the concept of *attentional bias*, as applied to cognitive accounts of anxiety, is a vast topic. Interpretation of data arising from paradigms purporting to measure bias has led to a number divergent positions within the cognitive study of anxiety. The focus of this section, therefore, is twofold: (1) to describe the core research paradigms and data from which these positions take form, and (2) to elucidate the prominent theoretical positions of attentional biases in anxiety.

Stroop Paradigm

In a paper entitled "Studies of interference in serial verbal reactions", Stroop (1935) found that it took longer to name the color of a word when printed in an incompatible color (e.g., the word *RED* printed in Blue) than naming the color of solid color patches (Experiment 2) or swastikas (Experiment 3). Stroop concluded, "The difference in the time for naming the colors in which the words are printed and the same colors printed in squares (or swastikas) is the measure of the interference of conflicting

word stimuli upon naming colors.” (p. 659). Early versions of the Stroop task required participants to read columns of words. However, researchers later modified the task so that individual stimuli could be compared (MacLeod, 1991). Modification to the original task, now considered the classic Stroop experiment, require participants to read words printed in different colors and to name a words’ printed color. What results, as Stroop had found earlier, is that compared to incompatible conditions, participants: (1) effortlessly ignore the printed color of the word when reading the word, and, (2) participants are faster at naming the color of a word when printed in a compatible color, although response times are slower than just reading the word (the word BLUE printed in blue) (Cohen, Dunbar, & McClelland, 1990).

Subsequent to Stroop’s initial work, numerous variations of the task have been developed to investigate a range of psychological constructs (see MacLeod, 1991, for a comprehensive review). Figure 2-12 illustrates an example of Stroop’s original task (A), the variation as it is commonly used in emotion research (B), and a few additional versions for the interested reader (C). In particular, the emotional Stroop paradigm’s use in the study of affective disorders has been widespread (Williams, Mathews, & MacLeod, 1996). The prototypical design is similar to the original Stroop task where a word is presented on the screen and is printed in some color. Upon appearance of the word, the participant is instructed to rapidly press a key corresponding to the word’s color. However, on some trials, the word may represent content specific to an individual’s worry or concern (e.g., the appearance of the word WEB for spider phobics). As a result, the meaning of the word theoretically interferes with naming the word’s color, as indicated by slowing of response time observed in comparison to control words (e.g.,

CABINET). This is indicative, according to some researchers, as a selective bias to process the content of the word indicated by the interference it produces in responding to the word's color (Williams et al., 1988).

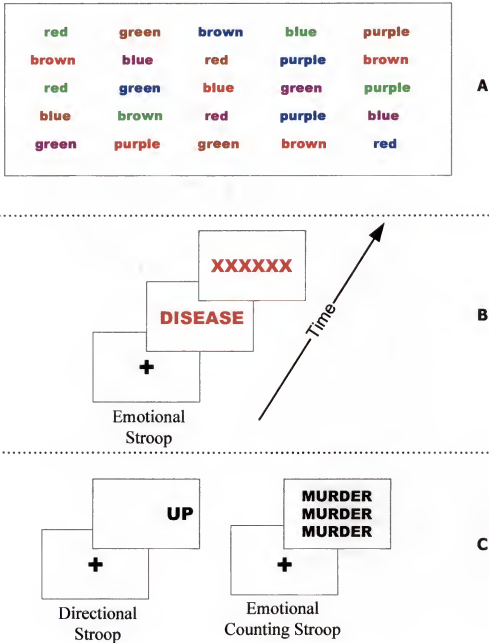


Figure 2-12. Variants of the Stroop task. A) Traditional Stroop, B) Emotional Stroop, C) Directional and Emotional Counting Stroop

A few additional variations of emotional Stroop are prevalent in research on affective disorders. Similar to the basic emotional Stroop methodology mentioned above, stimuli may be presented at subthreshold levels (< 30 ms) where participants are unable to consciously recall what word they had previously seen. This is accomplished using a *backward masking paradigm*, in which a stimulus is blocked from processing by masking it with another stimulus closely in time. As shown in the middle panel, backwardly masked words are quickly followed with a series of X's, or for pictures, masked by cut-up and randomly assembled pieces of the original image. Subthreshold versions of the emotional Stroop task arguably allow assessment of subconscious processing of emotional information (Bradley, Mogg, Millar, & White, 1995; MacLeod & Rutherford, 1992). Other major variations include the pictorial Stroop (pictures are superimposed on a color circle), and the emotional counting Stroop (word interferes with the ability to count the number of words simultaneously presented; Lavy & van den Hout, 1993; Kindt & Brosschot, 1997), Whalen et al., 1998).

In the most comprehensive review of the emotional Stroops' use in the study of affective disorders to date, Williams et al. (1996) reviewed 53 studies using the Stroop paradigm in the anxiety spectrum disorders and depression. To summarize, seven major themes emerged:

- *Interference effects observed with the Stroop task are relatively robust to varying methodologies.*
- *Color-naming latency is delayed for words specific to an individuals' principle worry or concern serve as stimuli.*
- *Interference effects vary as a function of both state and trait dimensions of anxiety.*

- *PTSD produces the largest interference effects compared to the other affective disorders reviewed.*
- *Sub-threshold presentations of emotional Stroop stimuli produce interference effects with little exception.*
- *Interference effects diminish following treatment.*
- *Interference effects are not exclusive to negatively valenced stimuli, but color-naming latency for positively valenced stimuli related to individual concern has also been noted.*
- *It remains unclear what to attribute the null findings of interference effects under certain conditions. For example, why do phobics exhibit slowed color naming latency to words representing their phobia, but do not occasion slower performance when told that their feared object is present during testing (i.e., strategic override)?*

For more than half a century, the Stroop paradigm and its derivatives have been integral tool in the formulation of many cognitive accounts of anxiety. While the mechanism(s) responsible for producing the interference effects seen in Stroop tasks are still being actively pursued, some researchers have argued that the reliance on interference effects to observe attentional biases is problematic (MacLeod, 1991; 1999). MacLeod (1999) has argued that the explanation of increased attentional allocation or bias to threatening material, which is deduced from increased interference to color naming, is only one of many possible ways to account for slowed color naming. Another possible explanation, according to MacLeod, is that attention is “diverted” away from the word producing the observed pattern of bias. Furthermore, MacLeod (1991) has also

argued that delays in color-naming might also be a product of response competition at the output stage (response selection) of processing.

Dot-Probe Paradigm

The development of the dot-probe paradigm, by MacLeod, Mathews, and Tata (1986), addressed some of the concerns regarding the mechanisms underlying the interference effects observed in Stroop tasks. In the original task design (see Figure 2-13), stacked pairs of neutral and threat words 5 cm apart would appear on a screen for 500 ms. On some trials following the offset of the words, a small dot would abruptly appear in the spatial vicinity previously occupied by one of the words. Participants were required to respond immediately to the appearance of this “dot probe” by pressing a response button. MacLeod et al. presumed that individuals would be faster to respond to the onset of the dot provided it is presented in a currently attended spatial location (Posner et al., 1980).

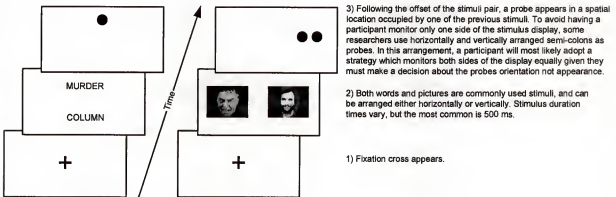


Figure 2-13. Dot-probe task

More specific to anxiety, if high anxious individuals preferentially attend to threat-related material relative to low anxious controls, they should then be faster to respond to a dot replacing threat-related cues. MacLeod and colleagues confirmed this conjecture with individuals diagnosed with GAD, and further noted that low anxious

controls tended to respond more slowly to probes replacing threat- than neutral-content, leading to the hypothesis that low anxious individuals were selectively attending away from this material. In general, this effect has since been replicated for individuals diagnosed with GAD (Bradley, Mogg, White, Groom, & de Bono, 1999; Mogg, Mathews, & Eysenck, 1992; Mogg, Bradley, & Williams, 1995), as well as extended to other classes of anxiety diagnosis such as social anxiety disorder (Asmundson & Stein, 1994; Mansell, Clark, Ehlers, & Chen, 1999; Musa, Lépine, Clark, Mansell, & Ehlers, 2003) and OCD (Tata, Leibowitz, Prunty, Cameron, & Pickering, 1996).

In addition to clinical research using the dot-probe paradigm, numerous studies have shown that highly anxious non-clinical samples also exhibit faster response times to probes replacing threat content (e.g., Bradley, Mogg, Falla, & Hamilton, 1998; Broadbent & Broadbent, 1988; Fox, 1993, 2002; MacLeod & Mathews, 1988; Mogg & Bradley, 1999). Some discrepancies with this proposition, however, merit caution in firmly concluding that faster probe response latencies are a product of high-trait anxiety alone, and not a function of state anxiety, or an interaction of the two. As well, consideration for the salience of the stimuli used to capture attention influences whether faster detection latencies will be observed.

As mentioned, early probe detection studies primarily used words as the principal stimuli of interest. However, attempts to replicate these initial findings with other affective stimuli have not yielded as robust or consistent findings. Given that a primary function of the attentional system is to subserve emotional imperatives, the pattern of attentional biases are typically realized for low to moderate threat, while most subjects,

irrespective of anxiety level, display shorter response latencies to probes replacing highly negative material compare to neutral content (Mogg et al., 1998).

Similar to the Stroop paradigm, alternatives to the probe detection task have included modifications to the kinds of stimuli used (i.e., lexical, pictorial), alterations in stimulus presentation length (i.e., below perceptual threshold, at various suprathreshold presentation lengths), and manipulations of response parameters (i.e., manually, vocal, location of probe, orientation of probe). Despite the task's non-reliance on interference effects to infer attentional bias, a few limitations of this paradigm warrant consideration. First, the probe detection task cannot specify the initial direction of attentional orientation. Second, the dot probe task does not offer any insight into overt versus covert shifts of attention once the pair of stimuli are presented. Third, whether a strategy is adopted such that attention is switched rapidly between both stimulus locations cannot be ascertained from current versions of the paradigm.

Visual Search Tasks

Unlike Stroop and probe detection tasks, the application of visual search to investigate attentional bias in anxiety has been minimal. In these tasks, participants are presented with matrices of stimuli from which they must decide the presence or absence of a specific target stimulus among distractors. The implementation of this paradigm for questions pertaining to affective information-processing has generally included facial displays as the primary stimuli (e.g., Fox et al., 2000; Hansen & Hansen, 1988; 1989; Öhman, Lundqvist, & Esteves, 2001a), although exceptions exist with regard to the stimuli used (e.g., Öhman, Flykt, & Esteves, 2001b; Tipples et al., 2002). Despite variations in stimulus characteristics, the hypothesis that humans preferentially allocate attention to threat over other facial displays not signaling threat has been of particular

importance. If true, this might solidify the notion that attentional biases among individuals with phobias and other affective disorders may indeed contribute to their individual affective disorder.

Hansen and Hansen (1988) tested this hypothesis by presenting participants with 3 x 3 matrices of males and females displaying happy, angry, and neutral facial gestures. On some trials and within each of these categories (Experiment 1), a discrepant face was presented with one from another category (an angry face was presented in a matrix of neutral faces). Participants were asked to respond to the presence or absence of the discrepant stimuli. Hansen and Hansen reported that angry faces were identified more quickly in neutral- and happy- matrices, relative to how quickly neutral- or happy- faces in angry matrices were identified, tentatively supporting the notion that threat faces receive preferential processing.

Despite their encouraging results, Hansen and Hansen cautiously interpreted their findings, citing two potential competing hypotheses. First, they suggested that the frequency with which people encounter angry faces is less than neutral or happy faces. As such, their findings could be attributed to the novelty of the angry faces. Secondly, the researchers proposed that there is greater variation in the manner by which people display anger and neutral facial expressions as compared to happy facial gestures. According to Hansen and Hansen, this contention could explain why people are faster at detecting neutral- and angry- faces in matrices of relatively homogenous happy faces.

To remove some of this variability, a second experiment (Hansen & Hansen, 1988) exposed participants to matrices comprised of targets and distractors *from the same individual*. Despite sacrificing ecological validity, the manipulation permitted the

researchers to reduce the challenge of competing variability among the facial array and distractor as liable for decreases in detection speed. In this new arrangement, the researches similarly found decreased latencies for angry distractors in happy arrays than the contrary. In a final experiment, Hansen and Hansen sought to address whether the search strategy for the “face-in-the-crowd” effect was serial or parallel in nature. To accomplish this, the researchers again presented matrices of faces to participants (as in Experiment 2), however, varied the number of faces that appeared in a given matrix to be either four or nine faces. They reasoned that if people employ a parallel search strategy to detect threat, then matrix size should be an irrelevant factor in response time (Treisman & Gelade, 1980). Indeed, Hansen and Hansen found that angry targets were detected faster in happy arrays irrespective of display size, and the detection latency of happy faces angry arrays increasing with array size.

Despite existing evidence of for a “pop-out” effect for angry faces, some researchers disputed Hansen and Hansen’s (1988) claims (see Öhman et al., 2001a; 2001b). Revisiting this issue, Öhman and colleagues (2001a) attempted to replicate Hansen and Hansen’s findings; however, schematic drawings of faces were now substituted for the photographic facial stimuli used in the original studies. In the first experiment by Öhman et al., each stimulus set was composed of a 3 x 3 matrix of threatening, neutral, or friendly schematic faces (54 total) and distractors from each face subtype (54 total). Figure 2-14 illustrates the various arrangements used in the first experiment. Exposure durations of 1 s and 2 s were used. Participants responded to the presence or absence of a target among distractors with a key press.



Figure 2-14. Facial stimuli used by Öhman et al. (2001a)

Öhman et al. (2001a) reported that among neutral distractors, a threatening face was detected *faster* than friendly ones for both stimulus durations. On the other hand, among emotional distractors, participants were faster to detect a threatening face among friendly faces *only when presented at the longer stimulus presentation duration*.

Participants were, however, significantly more *accurate* at detecting threatening faces among friendly distractors for both stimulus durations. Given the context of Öhman's evolutionary perspective, discussed in a later section, findings supported the notion that humans preferentially process threatening information.

In an analog of this paradigm using pictures, Öhman et al. (2001b) presented unscreened participants with 3 x 3 matrices containing pictures of snakes and spiders (fear-relevant) among flowers and mushrooms (fear-irrelevant), and vice versa. The task was again to detect (with a button press) whether or not a discrepant target existed in the matrix, displayed for 1200 ms.

Consistent with the findings reported with schematic faces, the data indicated that participants detected fear-relevant stimuli more quickly than fear-irrelevant targets. In an attempt to delineate search strategy from these data, Öhman et al (2001b) could only tentatively conclude that fear-relevant stimuli prompted parallel search strategies, while search for fear-irrelevant material prompted more serial search strategies.

In follow-up studies using both schematic faces (Öhman et al., 2001a) and pictures of feared objects (Öhman et al., 2001b), the researchers sought to more directly test the hypothesis that search for threatening material occurs in parallel. In these experiments, Öhman and colleagues manipulated the size (number of items) of each stimulus matrix. For schematic faces and pictures, matrix sizes were 2 x 2 to 5 x 5 (4

total) and 2 x 2 and 3 x 3, respectively. For schematic faces, the detection latencies for both friendly and threatening faces among neutral distractors were found to be independent of matrix size, although threatening faces were detected slightly faster than friendly faces. Similarly for pictures, fear-relevant stimuli were detected faster than fear-irrelevant stimuli, however, fear-irrelevant pictures were detected significantly faster in the 2 x 2 compared to the 3 x 3 condition while no difference in matrix size was observed for fear-relevant pictures. For both experiments, an increase of less than 5 ms per search item was used as the criterion to determine whether participants were indeed engaged in parallel or serial searches (Treisman & Souther, 1985). This search slope, which, as previously mentioned, is calculated by dividing the average increase in response time by the total items in the matrix, was met for all matrix sizes for both friendly and threatening schematic faces but only for fear-relevant pictures.

Extending this paradigm to further explore attentional biases in threat processing, Öhman et al... (2001b, Experiment 3) screened for snake and spider fearful participants and exposed them to a similar protocol as in Experiment 2 (picture viewing terminated with response). Consistent with the results from the previously mentioned experiments, fear-relevant pictures were detected faster than fear-irrelevant pictures, with detection latencies for fear-irrelevant pictures increasing with matrix size but with no increase for fear-relevant pictures found. Most notably, the finding of faster detection latencies for fear-relevant pictures was shown to be enhanced for high fear subjects' expressly feared object. As demonstrated by Gilboa-Schechtman, Foa, and Amir (1999), the finding of fear specificity is evident with social phobics being faster at detecting angry faces compared to controls. Additionally, as previously mentioned, Williams et al. (1996) have reported

emotional Stroop findings consistent with the view that interference effects appear to be diagnostic for an individual's specific concern.

While the above series of experiments concur with the dominant view that detection of threatening information yields a more efficient search than non-threatening information, data obtained from other visual search tasks are not congruent with this assertion. For example, Tipples et al. (2002) confirmed the Öhman et al. (2001b) finding of faster response times to the appearance of a threatening target (attacking animals) among neutral distractors (plants), and like Öhman et al., concluded that this effect occurred independent of matrix size for threatening pictures. Using an estimate of parallel search comparable to Öhman et al. (2001a; 2001b) criterion of less than 5 ms, Tipples et al. reported an 11 ms search slope for threatening pictures, and a 28 ms search slope for non-threatening materials. Based on their findings, Tipples et al. postulated an explanation contrary to that offered by Öhman. They argued that because participants identified threatening animals more quickly among neutral distractors than vice versa, some unforeseen "visual properties" of the animal pictures might have drawn attention to them. To test this hypothesis, a second experiment was formulated in which pictures of threatening animals were paired with positively valenced animal pictures. Again, a similar pattern was obtained, with pleasant animals among neutral distractors detected significantly faster than the contrary. Moreover, a parallel increase in detection time was noted, with an 8 ms search slope for animal pictures and a 24 ms search slope in plant pictures reported.

These findings would seem to suggest that pictures of attacking animals do not receive preferential processing as indicated by Öhman's experiments. According to

Tipples and colleagues, an additional remedy for these disparate findings could be the homogeneity of distractor items in a given matrix. Based on this rationale, response times could potentially reflect the time needed to reject items in an array as opposed to the time needed to find the discrepant item. To explore this issue, heterogeneous arrays of neutral non-target stimuli were used as distractors. Again, similar results emerged for response latencies as in the previous experiments. That is, negatively valenced animal pictures were not detected with any advantage over positively valenced animal pictures.

The unqualified assertion that people preferentially process threat remains an ambitious proposal using visual search tasks. It appears that, with the exception of Tipples et al. (2002), consistent with other paradigms designed to delineate attentional bias toward threat, and under specific conditions and for specific stimuli, the extant data generally confirms that processing threat-related information is facilitated relative to neutral and positive stimuli. The studies cited above implementing schematic faces as stimuli support this claim, even for unselected participants. On the contrary, findings from visual search tasks using pictures have been ambiguous, but this is not out of the ordinary for alternative paradigms examining attentional bias to threat with unselected samples. Critical support for the position that attentional biases to threat are a feature of anxiety disorders was clearly provided by Öhman et al. (2001b), who found that fear-relevant pictures were detected faster among neutral distractors than the contrary. Furthermore, this effect was enhanced (detection latencies were faster) when participants viewed their own phobic object. Surprisingly few studies have examined the effect of state and trait anxiety interactively or alone as independent variables with visual search tasks using either schematic faces and pictures as stimuli. It will be interesting to see

whether future studies of this variety are needed to help clarify the conditions under which preferential processing of threat manifests in visual search tasks.

Exogenous Cueing and Inhibition of Return Tasks

In contrast to the dot-probe paradigm (intended to determine the preferential allocation of attention to negative information), support for a *disengagement* view of attentional biases in anxiety has been provided in the form of exogenous cueing tasks. The disengagement view states that biases in attention toward threatening information may not necessarily be a product of a preferential orientation to threat, but rather are associated with the difficulty of highly anxious samples to shift their attention *away* to competing stimuli. As mentioned, exogenous cueing (bottom-up) refers to a mode of attentional control where visual attention is directed to the appearance of new objects or modifications of an existing object. Otherwise stated, attentional allocation is stimulus rather than expectancy driven. Together with the concept of *inhibition of return (IOR)*, dubbed by Posner and colleagues (Posner & Cohen, 1984; Posner, Rafal, Choate, & Vaughn, 1985), exogenous cueing tasks form the foundation for inquiry into anxiety-related stimulus disengagement effects (Amir, Elias, Klumpp, & Przeworski, 2003; Fox, Russo, Dutton, 2002; Yiend & Mathews, 2001). IOR is considered an inhibitory mechanism that biases attention to novel or unsearched locations of the visual environment.

Adapting the exogenous cueing paradigm to investigate stimulus disengagement requires modification to the classic paradigm. First, the threat value of the initial peripheral cue must change. According to Fox et al. (2001; 2002), the logic of this arrangement is that if attention is held by threat cues for longer periods than neutral cues, response latencies will be longer for HA subjects on invalid trials compared to LA

controls. This is hypothetically attributed to the difficulty of HA subjects to orient or *disengage* their attention away from the threat cue. To help clarify how the exogenous cueing paradigm examines disengagement, consider Figure 2-15.

First, the participant is asked to maintain gaze on a centrally located fixation cross throughout the experiment. Second, either the left or right box is illuminated (cued location), where it is assumed that attention (not gaze) will likely make an exogenous shift to the cued location. However, in this case, a threat cue is substituted for the illuminated box. Third, the cue disappears. Fourth, after a brief period, a square or circle is presented at the cued or uncued location. Finally, participants respond to the appearance of the stimulus, pressing one of two buttons to categorize the target stimulus. The idea of this arrangement is that if individuals have a difficult time disengaging from a threatening stimulus, it should take longer to respond to a cue that appears in an uncued location. It should also be noted that while the purpose of this task is to assess disengagement of attention from various emotional stimuli, the initial orienting or attentional capture to a stimulus cannot be determined using this task.

Using an exogenous cueing paradigm to examine the hypothesis of whether highly state anxious individuals have difficulty disengaging from threat cues, Fox et al. (2001; Experiment 3) presented high- and low- state anxious participants with neutral, happy, and angry schematic faces. Highly state-anxious subjects were slower to respond to a target on invalid trials following an angry face compared to both neutral and happy faces.

4a) *Invalid trials/Short SOA* - participants must shift their attention to the uncued location because it is presumably still oriented to the initial cue. If HA subjects have difficulty diverting attention away from a threatening cue, they should be slower to respond to the appearance of the target compared to LA subjects.

4b) *Valid trials/Short SOA*, both HA and LA anxious participants exhibit faster RTs relative to invalid trials. However, depending upon the nature of the stimulus content, HA samples may tend to respond faster than LA samples at short SOAs.

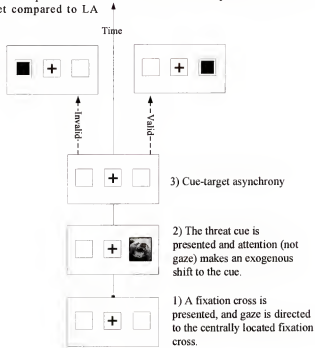


Figure 2-15. The inhibition of return paradigm has been modified to evaluate disengagement by replacing standard light cues with emotionally valenced picture or word stimuli. Following the presentation of a brief fixation cross, an emotional picture appears to the left or right. After a brief period (cue-target asynchrony), the spatial location occupying the previous picture stimuli (valid) or a spatial location not occupying the picture (invalid) is illuminated. Participants then respond (keypress) to the appearance of the cue.

A separate analysis for low-anxious participants did not produce these same patterns of results. In a replication and extension of these findings, Fox et al. (2002; Experiment 1) introduced a categorization task into the experiment. Additionally, the level of trait- (not state-) anxiety was the dichotomizing variable used for this experiment. Similar to the findings from the previous study, high-trait anxious participants were slower to categorize the target when it appeared in an invalidly cued location following an emotional (happy, angry) cue than neutral cue. Furthermore, the pattern was again not

observed for low-anxious participants, where cue valence does not appear to have any effect on response categorization latency to valid or invalidly cued locations. The finding that both happy and angry faces were comparable on invalidly cued trials for highly anxious participants was not explicated extensively, but did occur for valid cues in the Fox et al. (2001) study. In a similar experiment by Yiend and Mathews (2001, Experiment 2) that employed threatening and neutral pictures as cues, high-trait anxious participants were also found to be slower to respond to invalid targets compared to low-trait anxious participants.

In a second study (Fox et al., 2002, Experiment 2), cue-target SOA was increased to permit the IOR effect. Thus, time from the onset of the face cue to the presentation of the target stimulus was extended from 300 ms to 960 ms. By increasing the time between the cue and target, Fox et al., sought to test whether IOR was reduced in HA subjects provided they take initially longer to disengage from a threatening cue. While not specific to anxious participants alone, results suggested that the magnitude of the IOR effect, as indicated by response latency to the target, is reduced (shorter detection latencies) for angry faces compared to happy or neutral faces. Collectively, these results suggests that highly-anxious participants have difficulty disengaging from threat.

Theoretical Accounts of Anxiety and Corresponding Models

In following section, several prominent theoretical positions accounting for the empirical results above are described. Each subsection highlights a perspective and discusses any tangential information as it pertains to clarifying the given theory. In general, the presentation of each account occurs chronologically.

Biased Attentional Direction Account

An early two-stage account of anxiety emphasized the role of pre-attentive processes in the maintenance of anxious states (Williams et al., 1988). Figure 2-16 illustrates this model. As shown, an initial pre-attentive operation computing the relative threat or negativity of a stimulus is made by an *Affective Decision Mechanism* (ADM). The ADM yields threat assessments and generates an output that is passed to a secondary pre-attentive mechanism that allocates resources to deal with the current stimulus (*Resource Allocation Mechanism* [RAM]). This model advances the idea that threat-related stimuli will preferentially *capture* attention for clinically anxious and highly trait anxious non-clinical samples, but the reverse is predicted for low anxious controls suggestive of avoidance. This *interaction effect* is also argued to be more pronounced as state anxiety increases (Mathews & Mackintosh, 1998).

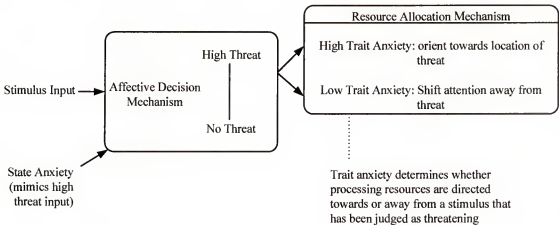


Figure 2-16. Williams et al. model of attentional bias. Allocation of attention toward a stimulus is determined by the output of an evaluative mechanism that assesses threat or the affective significance of a stimulus.

Later refinements by Williams and colleagues (1996), however, clarified a few concerns of the original model. Primarily, the pattern of avoidance for low anxious people under stress, as the model suggests, does not explain how stimulus intensity might

alter the interaction effect as stimuli become more arousing. That is, a fear detection system, or in this case, the ADM, would be dysfunctional if it did not direct the RAM to allocate resources to deal with a serious enough threat. A second concern of the original model involved the qualification that to observe attentional bias, competition between stimuli is a necessity. Yantis (1998), citing evidence from basic research in visual attention, made similar conclusions observing, "if the function of attention is to select relevant information from the visual field, then one might not expect to observe attentional effects in these circumstances" (p. 229). Some researchers have noted that presentation of single stimulus does not produce the expected latency bias as seen in typical dot probe methodology (Mathews, May, Mogg, & Eysenck, 1990; Williams et al., 1988). Thus, to better express why response competition is necessary to observe attentional biases, the ADM was reconceptualized to more closely resemble a connectionist network or *Parallel Distributed Processing* (PDP) network, described next (Mathews & Mackintosh, 1998).

Connectionists Networks in Anxiety

Connectionist networks, sometimes referred to as neuromorphic systems, are computerized implementations for modeling cognition, or more generally, the human mind (Goldblum, 2001). Two related terms, *artificial neural systems*, describing the industrial use of connectionist modeling (i.e., Route Optimization) and *neural networks*, which include both theoretical and industrial applications, do not always explicitly model brain systems (Levine, 1991). However, these terms all similarly describe "a system composed of many processing elements operating in parallel whose function is determined by network structure, connection strengths, and the processing performed at

computational elements or nodes” (Defense Advanced Research Projects Agency [DARPA], 1988, p. 60).

Conceptually, individual units (i.e., nodes) in a network are loosely symbolic of neurons. Like neurons, units can receive excitatory and inhibitory activation, and even vary in the threshold function to which they relay their output (Plunkett & Elman, 1997). Networks of this kind involve the integration of nodes linked together by connections that transmit weighted activation across the units (Green, 2001). For networks to learn, various algorithms are applied such that the relative weight (i.e., strength or weakness) of a given connection is altered. For example, the Cohen et al. (1990) paper mentioned above, utilized a delta-learning rule, in which a neuron's input is multiplied with the difference of its output and the desired output and a constant known as the network's learning rate.

Williams et al. (1996) integration of a connectionist framework to model the ADM was an adaptation of earlier work by Cohen et al. (1990) with the Stroop task. Cohen et al. demonstrated a PDP network able to simulate the interference observed in the Stroop task, in addition to the network responding to task variations such as stimulus-response asynchrony and amount of practice (Figure 2-17). In Williams et al. (1996) model, the ADM is described such that activation units representing a threatening stimulus (e.g., spider) are selectively “tagged” for their emotional content derived through biological innateness or prior learning. Because threat units are given preferential processing to other units in the network, the RAM would then allocate resources to deal with the present threat. According to Mathews & Mackintosh (1998), “Without any competition, however, no particular advantage would be apparent, because a single threat

stimulus would always effectively control output from that network, regardless of whether it contained the tag or not” (p. 541).

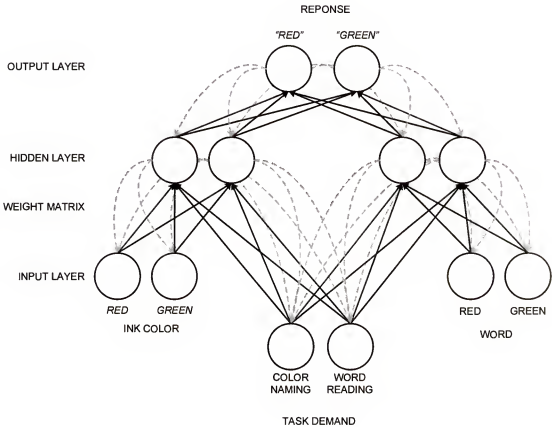


Figure 2-17. Network used by Cohen et al. (1990) to simulate the color naming interference effects observed in Stroop tasks. As depicted, the model consists of two primary pathways, one for processing ink color and the other for processing word information. “Processing” in this respect is defined as the propagation of signals from one node to another. These pathways can be seen to intersect with two task demand units on intermediate units in the hidden layer, which are meant to represent the allocation of attention to one task or the other (i.e., color naming or word reading). Information moves in feed forward fashion beginning with the input layer progressively through the network. Once a node receives its inputs, like a neuron, it may activate depending upon its’ defined threshold value, which determines if subsequent output to higher echelon nodes should occur. In Cohen and colleagues’ model, activation was determined by a logistic function. At each stage, connections strengths or weights (represented by the lines) are altered by computing the amount of error between the actual and expected output, including the networks leaning rate and bias indices. Once this error is calculated, it is backwardly propagated to each corresponding node, thus subsequent iterations

become closer to desired output. This arrangement is known as supervised learning where the network is first trained to establish connection strengths.

Strategic Monitoring for Threat Account

In contrast to the Mathews model of anxiety which emphasizes the role of preattentive processing as a contributing factor of attentional bias, Wells and Matthews (1994; 1996; Matthews & Wells, 1999) underscore that attentional bias may be a consequence of a *voluntary and effortful* strategy favoring excessive monitoring of the environment for threatening information. The researchers (1994, 1996) distinguish among three levels of analysis in which attentional bias may emerge. They refer to these as *biological*, *architectural*, and the *knowledge* levels. In the case of a spider phobic, for example, a biological level of analysis might explain attentional bias in the form of primitive neural circuits with a greater propensity to fire in the presence of objects that resemble spiders. At the architectural level, attentional bias would result from the brain preferentially processing spider-related information. Finally, the knowledge level explanation is directed at understanding how attentional bias is produced in response to a person's motivations or goals. The deployment of a *strategy* represents the application of voluntary effort to meet a desired goal, and thus, attentional bias is a product of an individual's plans and goals (Matthews & Wells, 1999).

Wells and Matthews (1994, 1996) are generally critical about strict *architectural* explanations of attentional bias. Architectural models of anxiety suggest that attentional biases are exclusively a product of low-level processing operations and insensitive to top-down influence. "The knowledge level explanation contrasts with the assumption of architectural explanations, that attentional bias is something of a computational accident, which feeds into a person's self-knowledge but is not affected by it" (Matthews & Wells,

1999, p. 174). In particular, they question models of attentional bias that cite Stroop and probe detection task as evidence, or argue that observation of bias is predisposing factor for an emotional disorder. Furthermore, they suggest that these tasks fail to discriminate between involuntary and voluntary contributions of bias, which both may lead to a strategic disposition that constantly monitors for threat (1994, 1996). For example, Matthews and Wells contend that subthreshold Stroop and probe detection tasks “fail to attain very stringent methodological requirements” and “none of the studies have assessed perceptual thresholds for individuals, or tested for awareness of stimulus valence independent of stimulus recognition” (Wells & Matthews, 1994, p. 884).

To integrate the three levels of explanation (i.e., biological, architectural, knowledge), which they argue are all important to understanding attentional bias, the researchers introduced the self-regulatory executive function (S-REF) model, depicted in Figure 2-18 (Wells & Matthews, 1994). The model is comprised of three interacting tiers. The bottom level is comprised of network of automatic stimulus-driven (internally and externally driven) response nodes. The second tier is comprised of a supervisory control executive that when activated, according to Matthews and Wells (1999), spawns the “initiation and monitoring of coping strategies, and the modification of self-knowledge” (p. 183). The third tier contains the individual’s self-knowledge and beliefs partitioned into a declarative and procedural knowledge (not shown).

As observed from the figure, certain aspects of the model are apparent. First, the notion of automatic and controlled processing comprising the lower and middle tiers of the model is evident. Second, they suggest that self-regulation, operating under controlled influences, is an ongoing effortful process. Third, the model noticeably excludes

biological influences, and rather is mostly concerned with the dynamic interaction between architectural and knowledge level explanations. At the architectural level, low-level processing units are conceptualized as a connectionist network, which receives top-down influences from self-regulatory goals.

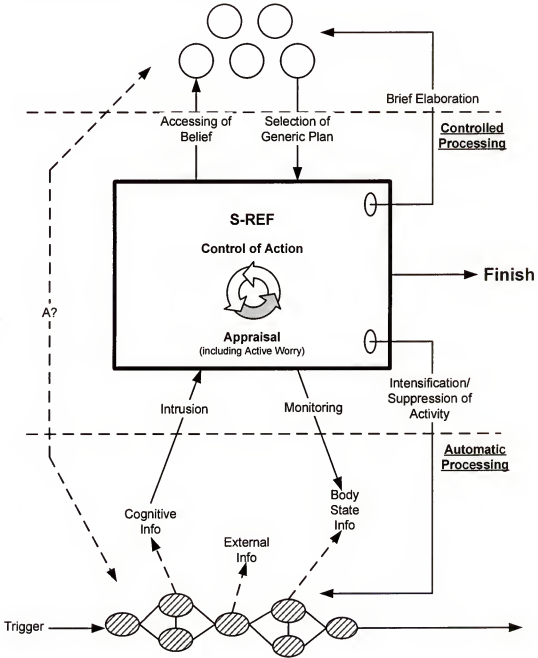


Figure 2-18. Wells and Matthews Self-Regulatory Executive Function model (S-REF).

To model this exchange, Matthews and Harley (1996) further explored the viability of connectionist networks to account for attentional bias observed in the emotional Stroop task as an extension of Cohen and colleagues (1990) work with connectionist modeling of the standard Stroop interference effect. Although their network was a loose derivative of Cohen et al. (1990), the researchers were not attempting to explicitly model response times. Rather, the pattern of responses generated by the network was of interest, which was derived from the mean square error (MSE) between the network's output and the desired output from training. At the knowledge level, self-beliefs and generic action plans to cope with a situation are represented at the top-tier. Integrating and actively exchanging information with both the upper and lower tiers is the self-regulatory executive. According to Wells and Matthews, "self-regulatory processing performs not only appraisal of the significance of external events and signals from the body but also serves a meta-cognitive function of appraising the personal significance of thoughts and guiding subsequent cognition" (1996, p. 882).

Cognitive-Motivational (Vigilance to Threat) Account

Much of the support for a *vigilance to threat* account of attentional biases in anxiety has come from Bradley, Mogg, and colleagues (Mogg & Bradley, 1998 for review). In their view, a clinical vulnerability to anxiety arises *from a lower threshold for appraising threat* as opposed to a specific bias in the direction of attention. While advocates of this account stress that attentional bias represents a vulnerability to anxiety, some researchers have demonstrated that bias effects are reduced following treatment (Matthews & Harley, 1996; Watts et al., 1986). Still, a cognitive-motivational model (see

Figure 2-19) postulates two systems that together function to mediate anxiety characteristics.

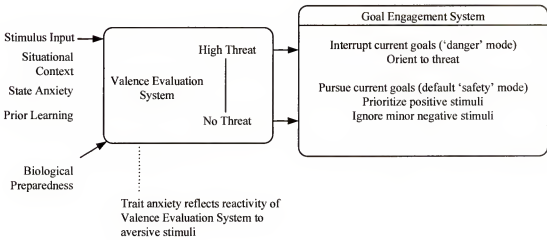


Figure 2-19. Bradley and Mogg's model of attentional biases.

First, the *Valence Evaluation System (VES)* functions to assess the relative threat value of a stimulus. Mogg and Bradley (1998) describe the VES in similar terms to that of Ledoux's (1995, 1996) description of a "quick and dirty" mechanism to analyze information from the incoming sensory stream. Additionally, the VES also serves to integrate other stimulus and environmental properties such as situational context, prior learning experiences, and biological preparedness. It is at the level of the VES that prioritization of stimulus processing occurs, with anxiety-prone individuals more likely to tag a negative stimulus as threatening.

A second mechanism postulated to operate efferent to the VES is the *Goal Engagement System (GES)*. The GES operates as a resources allocation mechanism that dedicates cognitive processing resources to stimuli. Given a low prioritization requisite of a stimulus tagged as having little or no threat value by the VES, the GES would subsequently allocate minimal processing resources to deal with the stimulus, thus

maintaining the current goal-directed behaviors of an organism. On the other hand, once a subjective threshold is reached, the VES may prioritize a stimulus as begin relatively threatening to an organism. In turn, ongoing goals and activities are interrupted, and the GES allocates more processing resources to deal with the present threat.

According to the cognitive-motivational perspective, attentional biases do not reflect a vulnerability to anxiety alone. For example, while a low trait anxious person would be more apt to disregard a stimulus evaluated as mildly threatening, as the level of threat increases, the amount of attentional bias to that stimulus will also increase (see Figure 2-20). This view is contrary to an earlier interactionist perspective supported by Williams and colleagues (1988, 1997), where the effortful allocation of attention away from a stimulus appraised as threatening increases for LA individuals. In this regard, “the presence of preattentive and attentional biases for mild threat stimuli, may be a sign of anxiety vulnerability, without necessarily being a determinant of such a vulnerability” (Bradley & Mogg, 1998, p. 820).

Enhanced Dwell-Time (Difficulty to Disengage)

The position that threat-related stimuli affects attentional-dwell time or the ability to disengage attention from threatening stimuli offers a competing view to the *vigilance to threat* perspective described above (Amir et al., 2003; Derryberry & Reed, 2002; Koster, Crombez, Verschuere, & Houwer, in press; Fox et al., 2001; Fox et al., 2002; Yiend & Mathews, 2001). While it is widely acknowledge that the dot-probe task only captures a snapshot of attentional allocation, inferences of vigilance to threat or a preferential priority of processing threat-related material is often claimed (Mathews & MacLeod, 1994; Mathews & Mackintosh, 1998; Mogg & Bradley, 1998). Critics of these

accounts suggest that attentional capture and maintenance cannot clearly be ascertained from probe-based tasks.

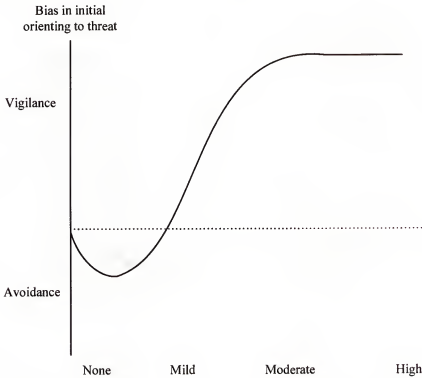


Figure 2-20. Shows the postulated pattern of vigilance/avoidance for an individual with low trait anxiety. This model contrasts with Mathews' interaction model.

For instance, the most common presentation length of 500 ms is long enough to allow multiple shifts of attention between each stimulus member in the pair. Attention may therefore not initially be deployed to the threat content, rather it may initially orient to the neutral cue, shift and then subsequently dwell on the threatening stimulus (Koster et al., in press). Thus, evidence suggesting enhanced latency from dot-probe paradigms may be interpreted as a difficulty to disengage from threat as opposed to the dominant view that threatening material preferentially captures attention in highly anxious participants.

However, a major problem for the disengagement account stem from findings from studies which incorporate gaze behavior as an index of attentional deployment during stimulus presentation. For example, Hermans, Vansteenwegen, & Eelen (1999) recorded eye movements while spider-anxious subjects viewed pictures containing spiders and neutral material (e.g., flowers). They found that individuals who feared spiders demonstrated fixation tendencies to spiders that were comparable to control participants during the early viewing period (i.e., first 1-2 seconds). In later epochs (i.e., the third second), however, control subjects exhibited significantly more fixations to the spiders while spider anxious individuals progressively fixated away from the spider stimuli. Eye movements away from the spider stimuli were interpreted to represent avoidance behaviors among these individuals, fostered by hypersensitivity to the fearful stimuli during early presentation. With regard to anxiety, similar findings to those of Hermans et al. (1999) were recently reported by Rohner (2002) who found that individuals with high trait anxiety did not differ from others in the early viewing period while viewing angry and neutral faces, but that during the later viewing period, they averted gaze from the negative stimuli (i.e., angry faces) significantly more so that did control subjects. Similarly, data from studies of individuals with body image problems have demonstrated that individuals avoid looking at regions of the body with which they are most dissatisfied, and that this tendency is more pronounced for those with high levels of body dissatisfaction (Janelle, Hausenblas, Fallon, & Gardner, in press).

Collectively, the results of existing eye movement studies only superficially disconfirm a disengagement account. Given the findings of Hermans et al. (1999), Rohner (2002), and Janelle et al. (in press) are strongly suggestive of avoidance and not a

difficulty to disengage, these results must be interpreted with caution, as none included a comparable measure of attentional engagement with viewed cues. As mentioned previously, to clearly draw inferences from eye movement indices, one must acknowledge the limitation that attentional orientation may not always follow gaze direction.

Evolutionary Preparedness Account

Similar to the previously described accounts of attentional bias, which postulate its co-occurrence as a byproduct and precipitating factor in anxiety, Öhman and colleagues (Mineka & Öhman, 2002; Öhman, 2000; Öhman & Mineka, 2001) regard bias as a functional consequence of the information-processing architecture that directs attention toward and provides cursory analyses of potentially threatening stimuli. This information is used, in turn, to support a defense system that operates to counteract threat. Figure 2-21 summarizes Öhman's (2000) information-processing model of anxiety.

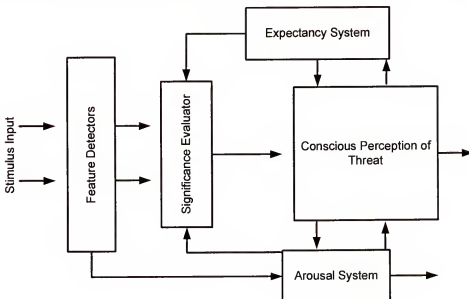


Figure 2-21. Öhman's information-processing model of anxiety.

As shown, incoming stimulus information is initially processed for indications of danger by preattentive *feature detectors*. Feature detectors are hypothesized to be particularly sensitive to stimuli with the properties of rapid rise time or high intensity, but also responsive to evolutionary old perceptual representations of threat (e.g., snakes, spiders). In the scenario where it is determined that a threat could potentially exist, this subsystem has direct outputs to an *arousal system* producing an “alarm reaction, which may eventually surface as an anxiety response” (Öhman’s, 2000, p. 584). As it relates specifically to attentional bias, Öhman suggests that the feature detection system may act as a significance filter that dually operates to (a) tag information for preferential processing by the *significance evaluator*, and (b) to activate the arousal system. The significance evaluator operates as a point of integration for information and processing imperatives from the feature detectors and arousal system; however, its analysis of stimulus input is dictated by an *expectancy system*. Accordingly, the significance evaluator is the central mechanism that operates to bias attention toward threat in a top-down fashion. If a threat is determined, output to a *conscious evaluation system* is produced and interferes with ongoing tasks. While the significance evaluator is not modeled as having any direct connections to the arousal system, depending upon the nature of output to the conscious evaluation system (shown as having direct links with the arousal system), conscious evaluation may backwardly propagate information indirectly to the significance evaluator via the arousal system, thereby biasing its subsequent output. Öhman suggests this feedback mechanism is responsible for the findings of state anxiety on attentional bias, where conscious perception of threat biases subsequent output from the significance evaluator, which subsequently biases attention.

More recent views of Öhman's evolutionary perspective of fear echoes the adaptation of specialized *modules* that have arisen to solve specific and prototyped challenges encountered during species evolution (Öhman & Mineka, 2001; Öhman & Wiens, 2003). Öhman and colleagues (2001; Mineka & Öhman, 2002) describe the following four characteristics of a module as: (1) *selective* or sensitive to stimuli that have posed challenges during the evolution of our ancestors, (2) exhibiting behavioral and neural *automaticity* with regard to the speed in which a response or strategic computation is initiated, (3) resistant to conscious cognitive influence, termed *encapsulation*, and (4) the organization of specific neural circuitry "shaped by evolution because it mediates the functional relationship between ecological events and behavior" (p. 486). Specific to the concept of a fear module, and the environmental context from which it is shaped by natural selection, Öhman argues that the fear module is particularly sensitive to evolutionary old threats to our ancestors:

Viewed from an evolutionary perspective, fear is central to mammalian evolution. As a product of natural selection, it is shaped and constrained by evolutionary contingencies... We are more likely to fear events and situations that provided threats to the survival of our ancestors, such as potentially deadly predators, heights, wide open spaces, than to fear the most frequently encountered potentially deadly objects in our contemporary environment (Öhman & Mineka, 2001, p. 483).

Biphase Theory and Natural Selective Attention

Common to each of the above perspectives is often an implicit inference that preferential processing or monitoring for threat occurs because harmful stimuli represent the greatest adaptive challenge to survival. Brain systems, therefore, have emerged over time to accommodate both primordial dangers, and to flexibly adjust to other environmental contingencies that may arise throughout an organisms' life-span. While this most certainly may be true, the above models have a difficult time parsimoniously

explaining why pleasant stimuli exhibit decreased response time in detection tasks and increased response time in interference tasks, paralleling observations with threatening stimuli. Without question, dangerous or threatening stimuli hold a great deal of adaptive importance, and for this reason, the progression of models which advance the notion of biased selective attention in emotional disorders appears to be a logical one. One could more generally argue, however, that it is the motivational relevance of a stimulus that ultimately dictates the commanding of attention when in the presence of competing stimuli, and syllogistically infer that *all* motivationally relevant stimuli invoke systems that necessitate the allocation of attention for more detailed and elaborative evaluation. Accordingly:

Since the 1960s, the concept of motivation has been somewhat neglected in psychology. Theory has been driven by the computer metaphor in which the brain is a machine for information processing and behavior is determined by output programs. Although the brain can be portrayed as a cool computational device, it is more accurately a biological organ that obeys evolutionary imperatives. Thus, motivational issues are central to any explanation of emotion" (Bradley & Lang, 2000, p. 247).

In their *Biphasic Theory* of emotion (Bradley, 2000; Bradley & Lang, 2000; Lang, 1995; Lang et al., 1990, 1992, 1997, 2000, 2002; Hamm, Schupp, & Weike, 2003), Lang and colleagues (2000) describe *natural selective attention* as attention "determined primarily by motivation...In natural environments, selective responding to one type of stimulus rather than another is dictated by the organism's pre-existing drive states—hunger, sexual needs, threat of harm." (p. 97). While the purpose of Biphasic Theory is not to explicitly make predictions with regard to attentional biases observed in anxiety, the theory does offer insight in conceptualizing other avenues from which attentional bias may emerge.

A basic tenet of Biphasic Theory suggests that natural selective attention processes by which human beings identify and process information is largely determined by the motivational significance of available stimuli, as dictated by their emotional characteristics. Attention, therefore, will be maintained by affective cues that are motivationally relevant to an organism as opposed to cues that are neutral in affective content (Lang, 2000). In this view, the observation that pleasant stimuli often mimic the enhanced detection and increased interference effects obtained in certain tasks appears to have foundational basis.

According to Biphasic Theory, emotions are action dispositions founded on primitive brain circuits, which organize behavior along approach-avoidance dimension (Lang et al., 1990). Specifically, the broad array of emotions experienced and displayed by human beings can be largely organized according to emotional intensity (i.e., arousal level), as well as the direction of affective valence (i.e., appetitive or aversive). Valence refers to the behavioral set, either appetitive or defensive, engaged by an organism, while arousal refers to the organism's disposition to react with varying degrees of intensity or activation (Lang et al., 1990). In the laboratory, a variety of media can be used to elicit a wide range of affective responses. For example, pictures (Lang, Bradley, & Cuthbert, 1999), words (Bradley & Lang, 1999a), and sounds (Bradley & Lang, 1999b), each sharing a similar biphasic organization on the dimensions of valence (pleasantness-unpleasantness) and arousal (degree of activation), have been used to study emotion.

In addition to understanding attentional biases in anxiety within the context of natural selective attention, Biphasic Theory parsimoniously merges data from three primary response systems. These include: (1) affective reports, such as responses to self-

report indices, (2) physiological reactivity, such as heart rate, skin conductance, cortical activity, and facial EMG, and (3) overt behavioral acts, such as patterns of avoidance or performance changes (Lang, 1969; Lang et al., 1997). If one were to survey data from the various cognitive accounts of attentional bias, it may be the case that further progress in understanding the roots of attentional bias has been stymied because theories which are explicitly attempting to account for bias do so with limited paradigms and response measures. Specifically, Stroop and dot probe tasks have been the favored experimental methods from which the various predictions have been tested. Perhaps the least utilized response system, noticeably neglected by the attentional bias literature, may potentially also have the greatest explanatory power when buttressed with data from other output systems. Physiological data, specifically, is certainly sparse when reviewing the various accounts and data of attentional bias.

Broadly speaking, the psychophysiology of emotion forms a major component of Biphasic Theory. For example, the match-mismatch hypothesis states that reflexes elicited during an emotional priming period will either be augmented or attenuated if they match depending the ongoing motivational state of the organism (Lang, et al., 1990). To capture this motivational priming effect, the startle reflex has been a widely used and accepted method to probe emotion and attention (e.g., Cuthbert et al., 1996; Cuthbert, Schupp, Bradley, McManis, & Lang, 1998; Lang, 1995; Lang et al., 1990; Schupp et al., 1997; Vrana et al., 1988). The startle probe typically consists of a stimulus, commonly a white noise burst, with central parameters that include rise time and intensity (Lang et al., 1990). In the context of Biphasic Theory, reflexes to a startle probe are predictably modulated by the affective and motivational properties of a stimulus (Vrana et al., 1988).

When viewing unpleasant (e.g., attack) as compared to neutral material (e.g., household objects), for instance, greater amplitude in the blink reflex is typically observed. On the other hand, when viewing pleasant (e.g., opposite sex nudes) as compared to neutral material, a reduction in the blink reflex is occasioned (see Lang et al., 1990 for a review).

The use of startle modification as a tool to investigate human emotion has certainly demonstrated its utility, however, and more globally, the integration of any psychophysiological measure would be a logical progression in examining the nature of attentional bias in anxiety.

Summary of Theories and Discussion

The primary purpose of this review was to provide a comprehensive overview of contemporary perspectives of attentional biases in anxiety. To achieve this objective, a major aim of this discourse was not only to unilaterally summarize those models citing attentional bias as a primary emphasis, but also to provide the platform from which those positions have emerged. To begin, the nature of *time*, as related to the rapidity in which an organism can identify, select, and deploy defensive behaviors when faced with a potentially dangerous encounter was introduced. Central to this theme was the assorted ways in which Darwinian natural selection has putatively operated to counteract the environmental pressures of predation. The examples provided were: (a) the organization of specialized neural circuits adapted to rapidly process visual information for potential threat (Doran & Ledoux, 1999; Ledoux, 1996, 2000); (b) the flexibility of local environments to shape an organism's net-predisposition to approach or avoid as suggested by the *Evaluative Space Model* (Cacioppo & Bernston, 1994, 1999); (c) the automatic preparation and genesis of physiological systems as predator imminence becomes more proximal as illustrated by the *Defense Cascade Model* (Lang et al., 1997);

and (d) the plasticity of defensive reflexes augmented as part of an organism's strategic defensive orientation (Lang et al., 1990). Antagonistic to these architectural and preparatory features designed to aid survival that was discussed included: (a) the abundance of information continually available to the various sensory modalities; (b) the capacity limitations of the nervous system; and (c) the variable distribution of threatening stimuli in the environment.

As one may have ascertained, the roots of the above theoretical frameworks share numerous commonalities with regard to fundamental concepts as they relate to basic information-processing and attention. Considering these similarities, differentiating among the aforementioned accounts is often subtle and is a matter of emphasis rather than exclusion. However, if one had to draw a conceptual distinction among the different models, the simplest division would be between those models arguing in favor for automatic capture or preattentive processing of threat and those that stress a top-down regulatory influence. Namely, this imaginary line would then separate Wells and Matthews S-REF model, which argues that bias originates from a top-down strategic monitoring process, from that of views held by Williams, Mathews, Bradley, Öhman and their respective colleagues. Part of this division stems from interpretation of subthreshold investigations of Stroop and probe detection studies employing backward masking procedures. As mentioned, Wells and Matthews argue that these paradigms do not demonstrate that attentional bias stems from early automatic processing because studies employing these techniques fail to accurately control for individual differences in threshold and the assessment of valence identification. Moreover, the issue of *what information can adequately be inferred by a given paradigm* also summarizes the current

division of the impaired disengagement view from these other accounts. The impaired disengagement perspective, for instance, argues that *attentional capture* cannot be ascertained from probe based detection tasks. As a result, Fox and colleagues use exogenous cueing tasks to support their position that highly anxious individuals have difficulty removing their attention away from threat. While this may be the case, it may also be true that highly anxious people have a greater propensity to orient toward threat, or that both rapid detection and sustained allocation of attention to threat may operate as part of a strategy that monitors the environment for negative information (i.e., S-REF model). Thus, the varied explanations may have arisen from the lack of specificity of the various paradigms that assess bias.

An issue that has been relatively neglected in this review and, more generally, in the accounts of bias above, is the specification of the stimulus properties that most likely will produce bias. In Stroop based studies, a common finding is that interference is often diagnostic for an individual's condition. That is, spider phobics generally take longer to respond to the color of spider-related words. Still, as it has been used herein, and in the attentional bias literature at large, the term *threat* is often loosely applied. Perhaps bias may occur more globally to all negative information and not specific to threats per se. If bias does occur to all negative information, what is the level of negativity in which bias disappears or that lack of bias is dysfunctional? What's more, is that positive information is often associated with the same processing biases as negative information. How then can this finding be understood within the present cognitive accounts of anxiety? A potential avenue for rectifying at least some of these issues is to understand what has been referred to as *natural selective attention* as described by Lang and colleagues (Lang,

Bradley, & Cuthbert, 1997). That is, the propensity to selectively attend to a given stimulus is largely a product of motivation, and accordingly, motivated attention is dictated by the affective properties of stimuli which may act to bias information processing and subsequently be expressed through the various response output systems (Lang, 1993).

With the exception of Öhman, the majority of evidence presented in accounting for attentional bias has been largely behavioral, typically in the form of simple or choice reaction time; though, eye-tracking measures have more recently been employed (Hermans, Vansteenwegen, & Eelen, 1999; Rohner, 2002). One observation of the various cognitive accounts of attentional bias is the relative lack of physiological evidence that may help to resolve burdening questions or, at the very least, inspire new explanations concerning why anxiety is associated with attentional bias to threat. A simple extension to any of the behavioral based experiments, for instance, would be to fractionate reaction time such that both central and peripheral components could be evaluated for their relative contribution to bias. Additionally, the use of event-related potentials may shed some light on the early allocation of attention to threat. In many respects, much can be learned from using psychophysiological tools to help understand the nature of attentional bias in anxiety.

CHAPTER 3
STARTLE EYEBLINK MODIFICATION AND ANXIETY: SHORT-LEAD
INTERVAL STARTLE INDEXES EARLY AFFECTIVE PROCESSING OF LEXICAL
STIMULI

Method

Participants

Table 3-1 shows the subject summary totals for all participants stratified by group. Participants included 32 low trait anxious (LTA) and 22 high trait anxious (HTA) students from the University of Florida who were recruited from undergraduate courses in exchange for a small amount of extra course credit. Participants were selected from a larger screening sample of approximately 400 students. Most participants described themselves as Caucasian ($n = 40$). Other racial groups represented in the sample included African-American ($n = 3$), Hispanic ($n = 4$), and Asian ($n = 4$). The majority of participants were Sophomores ($n = 24$), followed by Seniors ($n = 14$), Juniors ($n = 12$), and Freshman ($n = 3$).

The LTA group was comprised of 5 males and 27 females, with a mean age of 20.09 (1.23) years. The HTA group was comprised of 3 males and 19 females, with a mean age of 20.66 (2.10) years. Due to equipment problems and/or errors, physiological data was missing for two LTA and two HTA participants. Final sample sizes for each group were: LTA ($n = 30$) and HTA ($n = 20$).

Table 3-1. Participant characteristics listed by group.

	Low Trait Anxious	High Trait Anxious	Totals
Age	20.66 (2.10)	20.09 (1.23)	20.43 (1.81)
Gender			
Male	5	3	8
Female	27	19	46
Class			
Freshman	2	1	3
Sophomore	12	12	24
Junior	8	4	12
Senior	9	5	14
Grad	1	0	1
Race			
Caucasian	25	15	40
African-American	2	1	3
Hispanic	3	1	4
Asian	1	3	4
Other/Not Specified	1	2	3
Height (in)	65.19 (3.80)	65.64 (3.14)	65.37 (3.52)
Weight (lbs)	136.13 (23.90)	144.82 (40.81)	139.67 (31.82)

Materials, Apparatus, and Procedure

State-Trait Anxiety Inventory (STAI; Spielberger et al., 1983). Both state and trait anxiety were assessed using the STAI. Each dimension of the STAI (i.e., state and trait) consists of a 20-item questionnaire, which ask respondents to indicate how they feel about a particular statement using a 4-point scale anchored at the extremes with 1 (Almost Never) to 4 (Almost Always). High scores reflect greater state/trait anxiety. STAI scores have typically demonstrated sound psychometric properties, including inter-

item consistency, predictive validity, differential stability for trait anxiety (i.e., test-retest reliability $\sim .75$), and divergent validity (Spielberger et al., 1983).

Positive Affect - Negative Affect Schedule (PANAS; Watson, Clarke, & Tellegen, 1988). The PANAS is a 20-item measure used to assess positive ($n = 10$) and negative affect. Respondents are asked to indicate the degree to which a particular adjective reflects their current feelings or emotions using 5-point scale anchored from 1 (very slightly or not at all) to 5 (extremely). The PANAS has been found to consist of two dominant and relatively independent dimensions that have adequate psychometric properties (Watson et al., 1988).

Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988). The BAI is a 21-item instrument that assesses common subjective, somatic, or panic characteristics associated with anxiety. The inventory lists a number of symptoms and asks respondents to rate their correspondence with each symptom during the past month from a 'Not at all' to 'Severely-it bothered me a lot'. A score between 0 – 21 indicates low anxiety, a score of 22 - 35 indicates moderate anxiety, and a score over 36 may indicate a clinical anxiety disorder. The BAI has been shown to have adequate psychometric properties (Beck et al., 1988; Steer, Ranier, Beck, & Clark, 1993).

Lead stimuli

The lead stimuli will consist of 128 words selected from the ANEW (Affective Norms for English Words; Center for the Study of Emotion and Attention [CSEA-NIMH], 1999). Of these words, 64 comprised the threat (i.e., unpleasant) category, with 32 of these words being rated as highly arousing⁴ (HAT; *Mean SAM Valence* = 1.95, *SD*

⁴ *High Arousing Threat Words* (HAT) – abuse, anger, assault, cancer, demon, disaster, hatred, horror, killer, murder, mutilate, rape, stress, terrible, toxic, tumor

= 0.37; *Mean SAM Arousal* = 6.91, *SD* = 0.53) and the other 32 rated as low arousing⁵ (LAT; *Mean SAM Valence* = 2.36, *SD* = 0.51; *Mean SAM Arousal* = 4.56, *SD* = 0.62). Another 64 words represented pleasant content. Again, of these words, 32 were highly arousing⁶ (HAP; *Mean SAM Valence* = 8.08, *SD* = 0.38; *Mean SAM Arousal* = 7.50, *SD* = 0.27) and the other 32 low arousing⁷ (LAP; *Mean SAM Valence* = 7.90, *SD* = 0.30; *Mean SAM Arousal* = 4.93, *SD* = 0.29). Finally, 64 non-threat (or neutral) words⁸ closely matched for frequency of use and length were also included (N; *Mean SAM Valence* = 5.25, *SD* = 0.33; *Mean SAM Arousal* = 3.85, *SD* = 0.40). Figure 3-1 depicts category distribution for both valence and arousal.

Lexical lead stimuli were presented in 72 point Arial typeface in white capital lettering slight above center on a black background on a 19 in. computer monitor (800 x 600 x 16, Gateway Diamandtron VX920). The monitor refresh rate was set to 120 Hz and monitor calibration was performed using E-Color 3Deep software. Despite the fast monitor refresh rate (~ 8 ms), but given the necessity for lead interval determinism, careful consideration was placed to assure accurate lead interval time between the appearance of the word and the onset of the startle signal. The appearance of the lead stimulus (i.e., the start of the lead interval) was determined by monitoring a small 0.5 x

⁵ *Low Arousing Threat Words* (LAT) – ache, bored, coffin, crude, failure, fever, filth, garbage, gloom, illness, lonely, loser, penalty, sad, sick, unhappy

⁶ *High Arousing Pleasant Words* (HAP) – cash, desire, ecstasy, erotic, excitement, graduate, joy, kiss, miracle, orgasm, passion, romantic, sex, surprised, thrill, win

⁷ *Low Arousing Pleasant Words* (LAP) – adorable, beauty, caress, enjoyment, family, friendly, kindness, luxury, nature, paradise, rainbow, respect, satisfied, spouse, sunrise, truth

⁸ *Neutral Words* (N) – ankle, appliance, bandage, bandage, banner, barrel, basket, bench, butter, cabinet, clock, context, cord, cork, corner, cow, curtains, elbow, elevator, engine, fabric, finger, hat, hay, humble, icebox, industry, item, journal, kettle, key, lawn, material, medicine, month, nonchalant, office, orchestra, patent, patient, pencil, phase, plain, poster, prairie, quart, reserved, reverent, salad, serious, sheltered, sphere, statue, stove, table, theory, tower, trumpet, umbrella, vest, wagon, whistle, windmill

0.5 cm square placed in the upper right-hand corner of the monitor, which changed (i.e., toggled from black to white) in conjunction with the word stimulus.

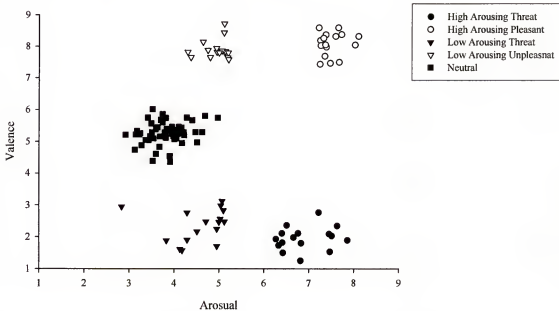


Figure 3-1. Shows the distribution of word categories for valence and arousal based on normative SAM ratings for all subjects.

The patch was covered with black electrical tape, and was invisible to the subject throughout the experiment. A visible light-sensitive silicon phototransistor (Vishay Semiconductors, BPW76) (rise time 6 μ s) was mounted directly above the patch just over the computer monitor. Prior to the start of a trial, the phototransistor was sampled at 10 KHz timed with a 20 MHz time base hardware clock using a National Instruments A/D board (E-Series PCI- 6034). In addition to buffering audio information for the pulse, a counter channel on the DAQ board was pre-initialized with a handshaking finite pulse with a delay parameter equal to the lead interval length (e.g., 40 ms) ending with a high state signal. Because the voltage produced by the patch is known for both light and dark states, an analog threshold was set to initiate the output of the counter channel, which initiated output of the audio information (i.e., startle pulse) contained in

the sound buffer. Taking these steps provides sufficient time resolution for the different lead intervals, and reduces variability due to software latency jitter. Other settings pertinent to increasing determinism between the onset of the lead and pulse stimulus can be found in the index.

Apparatus

The startle stimulus was comprised of a 50 ms broadband white noise pulse, with near instantaneous rise time presented at 106 dB SPL (A). The pulse stimulus was delivered binaurally using Sony headphones (MDR-V700DJ) connected to a 24-bit Sound Blaster Audigy soundcard (Creative Technologies, Ltd., Milpitas, CA). Sound calibration was completed prior to testing each participant using a Radio Shack (33-2055, Fort Worth, TX) digital sound level meter in conjunction with an acoustical calibration coupler (DR1; Digital Recordings, Halifax, Nova Scotia).

Physiological Data Collection and Reduction

A program written in LabVIEW (7.0; National Instruments; Austin, TX) coordinated the trial timing, stimulus events, and digital triggering for the collection of physiological data. Electromyographic (EMG) activity of the orbicularis oculi muscle was recorded using two 4 mm Ag/AgCl (EL204S; Biopac Systems, Santa Barbara, CA) electrodes positioned according to the guidelines recommended by Berg and Balaban (1999) for the left eye. Participant's skin was prepared by gently rubbing the electrode site with a sterilized gauze pad and distilled water. Having the participant gaze directly ahead, the first electrode was placed directly underneath the participant's lower eyelid inline with the pupil, and the second electrode was placed 1.5 cm lateral and slightly superior to the first. To reduce noise, electrode leads were interleaved prior to interfacing with the bioamplifiers. Raw signals were amplified by 5000, and were filtered using a

passband of 10-500 Hz (80 dB/Octave; EMG100B; Biopac Systems). Electrode impedances were kept below 20 K Ω .

Acknowledge software (3.7.2, Biopac Systems) was used to interface an MP150 control module (12-bit A/D converter; Biopac Systems) via a patch cable and signals were sampled at 25 kHz from 500 ms prior to lead stimulus onset and for 1.5 s following pulse offset. The high sampling rate allowed the audio signal to be captured along with the physiological data.

Raw EMG waveforms were rectified and then smoothed online using an FIR windowed filter (i.e., Hamming Window, 101 Coefficients) with a low-pass cutoff frequency set at 40 Hz (van Boxtel & Blumenthal, 2003). The waveform was subsequently baseline corrected by subtracting the mean 250 ms prestimulus baseline from each data point in the waveform.

To establish the dependent measures of interest for the eyeblink response, the following information was obtained using computer-assisted scoring. First, for a given trial, *response magnitude* was determined by locating the waveform peak within a 20-150 ms window following the acoustic startle stimulus. Once this value was determined, blink magnitude was converted to proportion of difference scores by subtracting the average response on pulse alone trials from each prepulse condition and dividing that value by the average response on control trials (Blumenthal, Elden, & Flaten, 2004). Third, *response probability* was determined by dividing the total number of trials in which a response was detected by the total number of trials in which the startle stimulus was delivered. Prior to data analysis, rejection, non-response, and exclusion criteria were established for both trial and participant data. Trials with an unstable baseline were discarded, and second,

trials in which a detectable EMG response did not occur within a 20-150 ms window were scored as zero.

Procedure

Approximately 400 students were screened using the STAI from courses in the Department of Applied Physiology and Kinesiology. The mean STAI trait score was 36.72 (*Median* = 36, *SD* = 8.09; *Range* = 44), with the lower and upper quartile cutoffs at 31 and 42, respectively (see Figure 3-2). Participants were recruited from ascending scores in the lower and descending scores in the upper quartiles of the screening sample, respectively.

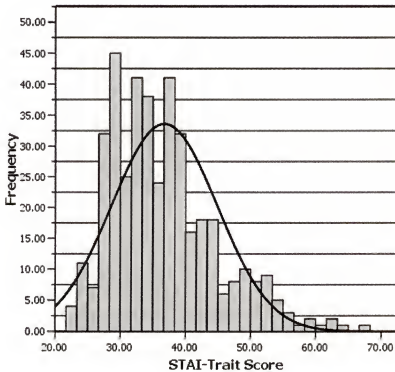


Figure 3-2. Histogram of STAI-Trait scores by frequency from screening samples in the Spring 2005 term. Data is from predominantly undergraduate male and female students enrolled in activity and other courses in the Department of Applied Physiology and Kinesiology.

Following completion of a University approved informed consent (see Appendix A and B), participants were seated in a comfortable chair in a sound attenuated room (ambient noise level ~60 dB) with the room temperature ranging from 73 to 75 degrees Fahrenheit. Participants then completed the state version of the STAI. Electrodes were affixed and the headphones situated. Participants were instructed to maintain their gaze on a computer monitor approximately 2 m front of them for the entire length of the experiment, and were told that they will see words appear on the screen in front of them. They were also told that they may hear a loud sound come from the headphones periodically that should be ignored. Throughout the experiment, a dialog window appeared every 16 trials which read, “trial break, press the spacebar to proceed”. Upon appearance of the dialog, participants were asked to simply press the spacebar when they were ready to proceed with the next group of trials.

The entire testing session lasted about 30 minutes, and was comprised of 128 trials divided over 2 blocks. Each trial block contained 64 trials, with the 4 lead intervals (i.e., 40, 50, 60, 240) represented twice for each word type (i.e., HAT, LAT, HAP, LAP). Sixteen neutral stimuli per trial block were used to match the cumulative total of the other category types. Stimulus orders were pseudo-randomized for each participant and within both testing sessions such that no single word category occurred more than twice in succession (e.g., the sequence HAT, LAT, HAT would not be permissible). Individual words were also randomized to occur across the various lead intervals. Of the 64 trials presented within a given block, a total of 8 trials, one from each lead interval and picture type (i.e., 4), and 4 neutrals from each lead interval (i.e., 16), were randomly selected to not receive a startle. This left a total of 7 trials per lead interval and word category for

Table 3-2. The table presents a prototypical trial block.

Trial	Word	Category	Lead Interval	Trial	Word	Category	Lead Interval
1	ORCHESTRA	N	-1			ITI	
2	SURPRISED	HAP	50	33	FAMILY	LAP	60
3	KETTLE	N	-1	34	CLOCK	N	-1
4	WIN	HAP	40	35	ELBOW	N	-1
		ITI		36	ASSAULT	HAT	-1
5	SHELTERED	N	-1	37	TOWER	N	-1
6	CASH	HAP	-1			ITI	
7	COFFIN	LAT	40	38	DEMON	HAT	240
		ITI		39	WAGON	N	50
8	TUMOR	HAT	240	40	HAY	N	240
9	BANDAGE	N	60	41	SUNRISE	LAP	50
10	SALAD	N	-1	42	CRUDE	LAT	-1
11	KINDNESS	LAP	40	43	FILTH	LAT	240
12	PRAIRIE	N	-1	44	TRUTH	LAP	60
13	ACHE	LAT	60	45	PLAIN	N	-1
14	BASKET	N	240	46	REVERENT	N	40
15	ILLNESS	LAT	50	47	FAILURE	LAT	240
16	KEY	N	240	48	RAINBOW	LAP	240
17	THRILL	HAP	60			ITI	
		ITI		49	WINDMILL	N	60
18	RESPECT	LAP	50	50	DISASTER	HAT	60
19	CORK	N	240	51	MIRACLE	HAP	240
20	GARBAGE	LAT	60	52	CONTEXT	N	-1
21	CABINET	N	60	53	BENCH	N	-1
22	ORGASM	HAP	240	54	RAPE	HAT	50
23	RESERVED	N	50	55	MUTILATE	HAT	50
24	APPLIANCE	N	-1	56	LAWN	N	-1
25	MURDER	HAT	40	57	QUART	N	50
26	SEX	HAP	50			ITI	
		ITI		58	STRESS	HAT	60
27	CORNER	N	-1	59	TABLE	N	50
28	CARESS	LAP	40	60	LONELY	LAT	40
29	HAT	N	40	61	NONCHALANT	N	40
30	JOURNAL	N	60	62	INDUSTRY	N	-1
31	ADORABLE	LAP	-1	63	EXCITEMENT	HAP	40
32	MONTH	N	-1	64	PHASE	N	40

The gray rows marked 'ITI' denote startles elicited during the inter-trial interval.

potential scoring per participant (see Table 3-2 for an example trial block). In addition to paired trials, a total of 16 pulse alone trials were also presented. These effectively occurred during the inter-trial interval. Pulse alone trials were distributed such that 2 randomly occurred per every 16 trials throughout the experiment. Following completion of the experiment, participants completed the PANAS and BAI, and were debriefed and thanked for their participation.

CHAPTER 4

RESULTS

Table 4-1 presents means, standard deviations, and simple comparisons for the various questionnaires by Group. The highly trait anxious (HTA) group reported significantly greater trait anxiety (HTA [$M = 48.41$, $SD = 7.27$], LTA [$M = 31.78$, $SD = 4.16$]), and state anxiety (HTA [$M = 39.73$, $SD = 8.40$], LTA [$M = 30.22$, $SD = 6.37$]) as indicated on the STAI, as well as exhibiting significantly greater negative (HTA [$M = 24.60$, $SD = 7.14$], LTA [$M = 15.40$, $SD = 3.41$]) and less positive affect (HTA [$M = 31.25$, $SD = 7.37$], LTA [$M = 40.56$, $SD = 5.55$]), as indicated by the PANAS, compared to the low trait anxious (LTA) group. The HTA group also scored higher on the BAI relative to the LTA group, ($M = 15.68$, $SD = 13.06$) and ($M = 7.69$, $SD = 5.84$), respectively.

Multivariate Tests

Table 4-2 reports the response probabilities obtained for the current study and Table 4-3 presents the untransformed blink magnitude values for each group by lead interval and word category. Initially, a 2 (Group [HTA, LTA]) \times 4 (Lead Interval [40, 50, 60, 240]) \times 5 Word Type (HAT, LAT, HAP, LAP, N) multivariate analysis of variance (MANOVA) with repeated measures on the last two factors was proposed to assess proportion of difference scores computed from startle blink magnitude values. From hereafter, the term "magnitude" will be used when referring to these proportion of difference computations. This analysis, however, was confounded by within-groups variability of state anxiety. The analysis was modified such that state anxiety was entered

as a covariate, as such a multivariate analysis of covariance (MANCOVA) with the above design was performed.

Table 4-1. Questionnaire comparisons by Group.

<i>Scale</i>	<i>Low Trait Anxious</i>	<i>High Trait Anxious</i>	<i>t</i>	<i>α</i>
<i>Beck Anxiety Inventory</i>	7.69 (5.84)	15.68 (13.06)	<i>t</i> (52) = - 3.06*	.92
<i>State-Trait Anxiety Inventory</i>				
Trait Anxiety	31.78 (4.16)	48.41 (7.27)	<i>t</i> (52) = - 10.67**	.92
State Anxiety	30.22 (6.37)	39.73 (8.40)	<i>t</i> (52) = - 4.73**	.91
<i>Positive-Negative Affect Schedule</i>				
Positive	40.56 (5.55)	31.25 (7.37)	<i>t</i> (52) = 5.30**	.90
Negative	15.40 (3.41)	24.60 (7.14)	<i>t</i> (52) = - 6.33**	.88

p < .05*, *p* < .01**

As shown, highly trait anxious participants scored significantly higher on the BAI, both the state and trait versions of the STAI, and exhibited significantly less positive, and more negative affect on the PANAS relative to low TA participants.

The omnibus multivariate procedure including both blink magnitude and onset latency produced a significant Group x Category x Lead Interval interaction, $F(12, 612) = 3.62, p < .001, \eta^2 = .07$. As well, a significant Category, Lead Interval x State Anxiety interaction emerged by introducing state anxiety as a covariate, $F(12, 612) = 2.25, p < .05, \eta^2 = .04$. A significant main effect for Category also emerged, $F(4, 204) = 2.77, p < .05, \eta^2 = .05$. Both the within-subjects main effect for Lead Interval and the between-subjects main effect for Group were nonsignificant.

Table 4-2. Means and standard deviations for startle eyeblink response probabilities listed by Group and Lead Interval as a function of Word Category.

Category	Group							
	<i>Low Trait Anxious</i>				<i>High Trait Anxious</i>			
	40	50	60	240	40	50	60	240
<i>Unpleasant</i>								
Low	.93	.96	.95	.95	.98	.96	.93	.97
Arousing	(.146)	(.150)	(.145)	(.149)	(.077)	(.122)	(.190)	(.091)
High	.97	.93	.96	.94	.97	.93	.98	.96
Arousing	(.109)	(.231)	(.115)	(.162)	(.091)	(.231)	(.112)	(.103)
<i>Pleasant</i>								
Low	.88	.97	.94	.97	.93	.96	.97	.96
Arousing	(.228)	(.094)	(.131)	(.086)	(.166)	(.131)	(.091)	(.122)
High	.98	.98	.95	.98	.96	.97	.98	.95
Arousing	(.091)	(.075)	(.143)	(.137)	(.092)	(.091)	(.074)	(.112)
<i>Neutral</i>								
	.96	.98	.97	.97	.96	.94	.95	.94
	(.067)	(.083)	(.065)	(.071)	(.092)	(.131)	(.113)	(.118)

Response probability is obtained by scoring trials with a detectable startle response as 1 and scoring trials without a detectable response as 0 and then taking the grand average for a given factorial combination.

Table 4-3. Means and standard deviations for startle eyeblink response magnitude listed by Group and Lead Interval as a function of Word Category.

Category	Group							
	<i>Low Trait Anxious</i>				<i>High Trait Anxious</i>			
	40	50	60	240	40	50	60	240
<i>Unpleasant</i>								
Low	.492	.525	.524	.546	.427	.516	.469	.532
Arousing	(.066)	(.071)	(.07)	(.078)	(.074)	(.086)	(.095)	(.104)
High	.508	.523	.472	.503	.463	.479	.505	.509
Arousing	(.07)	(.067)	(.06)	(.073)	(.098)	(.108)	(.109)	(.096)
<i>Pleasant</i>								
Low	.453	.531	.486	.524	.558	.492	.48	.522
Arousing	(.057)	(.081)	(.068)	(.066)	(.113)	(.116)	(.086)	(.107)
High	.483	.545	.418	.536	.446	.449	.487	.509
Arousing	(.066)	(.077)	(.065)	(.07)	(.084)	(.073)	(.089)	(.105)
<i>Neutral</i>								
	.47	.505	.495	.523	.475	.476	.485	.517
	(.06)	(.067)	(.063)	(.067)	(.099)	(.09)	(.094)	(.109)

Blink Magnitude Univariate Tests

A significant Group x Category x Lead Interval interaction was obtained for the blink magnitude univariate test, $F(9.34, 500.60) = 2.66, p < .01$ (See Figure 4-1, and see Figure 4-2 for a plot of control trial blinks for each startle presentation during the ITI).

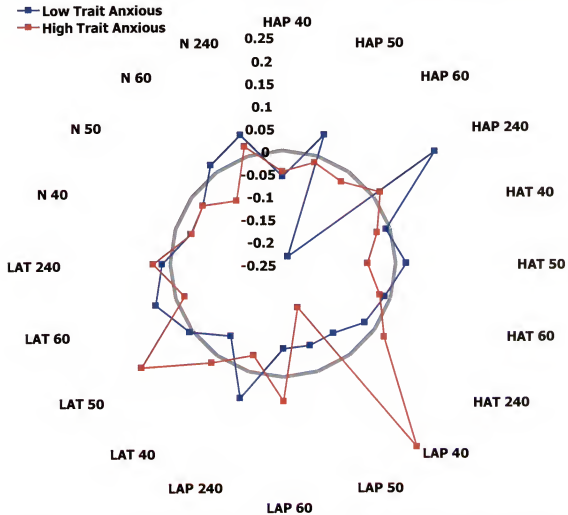


Figure 4-1. Polar plot of each word category and lead interval representing proportion of difference scores for all subjects ($N = 54$). Values occurring above zero and toward the perimeter reflect blink facilitation, while values occurring closer to center represent blink inhibition relative to control trials.

As shown in the figure, the interaction was partially driven by a strong, but nonsignificant, linear trend between low and high anxious participants to the low arousing threat words at a lead interval of 50 ms, with highly trait anxious participants

exhibiting larger difference scores ($M = .136, SD = .55$) compared to low trait anxious participants ($M = .005, SD = .45$). Still, relative to neutral words at 50 ms, HTA subjects occasioned greater blink facilitation relative to neutral words at 50 ms ($M = -.033, SD = .37$), while LTA subjects did not exhibit this difference. Contrary to previous studies (Aitkens et al., 1999; Waters et al., 2001), blink facilitation was not observed for either low or high arousing threat words at 60 ms between groups, nor relative to neutral words.

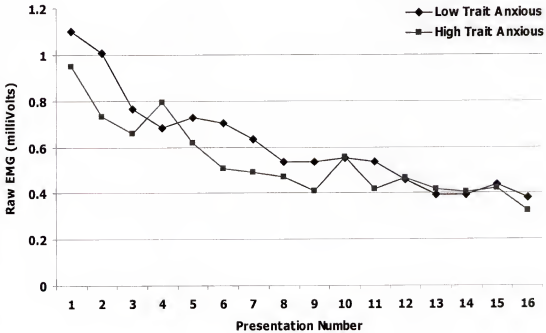


Figure 4-2. Show the blink habituation curve for both groups for each presentation of the startle probe during the ITI.

In addition, the HTA group occasioned a large blink facilitation effect for low arousing pleasant words at 40 ms ($M = .247, SD = .887$), compared to LTA subjects ($M = -.061, SD = .53$) and relative to viewing neutral words at 40 ms ($M = -.038, SD = .32$). HTA subjects also exhibited significantly less blink inhibition for highly arousing pleasant words at 60 ms ($M = -.027, SD = .30$) relative to the LTA controls ($M = -.230, SD = .36$).

A significant Category x Lead Interval x State Anxiety interaction was also obtained, $F(9.81, 500.60) = 1.89, p < .05$, once STAI state anxiety was introduced as a covariate. Table 4-4 displays the adjusted means and standard errors for this interaction.

Table 4-4. Means and standard errors for startle blink magnitude values listed by Lead Interval and Category adjusted by State Anxiety.

Category	Lead Interval			
	40	50	60	240
<i>Unpleasant</i>				
Low Arousing	-.006 (.078)	.098 (.067)	.025 (.082)	.034 (.078)
High Arousing	-.022 (.076)	-.029 (.061)	-.005 (.069)	.024 (.070)
<i>Pleasant</i>				
Low Arousing	.131 (.094)	-.114 (.050)	.007 (.065)	.024 (.084)
High Arousing	-.044 (.055)	.028 (.067)	-.117 (.048)	.100 (.102)
<i>Neutral</i>				
	-.033 (.055)	-.027 (.052)	-.026 (.044)	.050 (.070)

Onset Latency Univariate Tests

The Group x Category x Lead Interval interaction for onset latency was not significant, $F(9.34, 476.53) = 1.60, p > .05$ (see Figure 4-3). However, while the univariate test for the Category x State Anxiety interaction only approached significance, $F(3.71, 189.09) = 2.38, p = .058$, a main effect for Category was observed, $F(3.71, 189.09) = 2.66, p < .05$. Means and standard errors for the adjusted Category values were as follows: (HAP; $M = 42.83, SE = .91$), (HAT; $M = 42.77, SE = .82$), (LAP; $M = 42.86, SE = .97$), (LAT; $M = 43.75, SE = .79$), (N; $M = 42.42, SE = 1.09$). Comparisons between these adjusted values were, however, not reliably different.

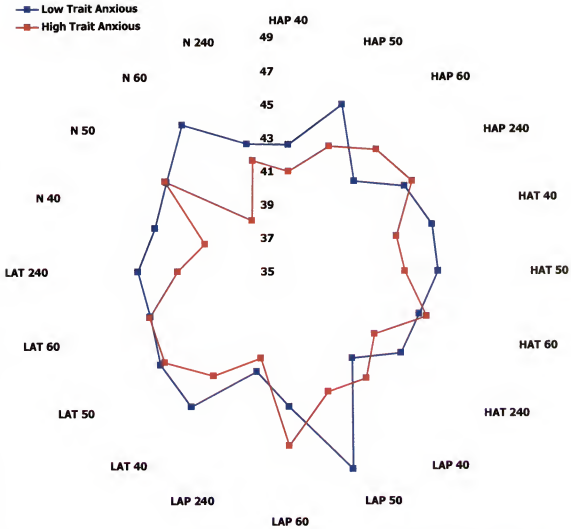


Figure 4-3. Polar plot of each word category and lead interval representing onset latency for all subjects ($N = 53$). Onset latency is defined as the time in ms from the occurrence of the lead stimulus until 20 percent of peak is reached. Mean replacement was used for those subjects not having an onset latency value for a given cell (total replacements = 15). Values away from center reflect longer onset latencies (blinked slower), while values occurring closer to center represent shorter onset latencies (blinked faster).

CHAPTER 5 DISCUSSION

The primary purpose of this study was to examine early information-processing of affective content in highly trait anxious and low trait anxious individuals. A short lead interval startle modification paradigm was used to evaluate how high- and low- trait anxious participants respond to high- and low- arousing unpleasant (threat), and pleasant words, in addition to neutral words at four different lead intervals (40, 50, 60, and 240 ms). This study sought to replicate and extend Aitken et al. finding for a blink facilitation effect for threat words compared to non-threat words at 60 ms for highly trait anxious individuals while also examining several additional objectives. Each of the findings is discussed relative to one of the primary objectives, and as pertaining to the study of attentional bias and anxiety. Limitations of the current study are also presented, followed by directions for future research.

An initial aim of this study was to replicate the blink facilitation effect to threat content for highly trait anxious subjects relative to low anxious controls at 60 ms. The study did not corroborate findings reported by Aitken et al. (1999) and Waters et al. (1999) that blink facilitation to unpleasant (threat) content is observed for people who are highly trait anxious at 60 ms (relative to neutral content at 60 ms) and compared to low trait anxious controls. Rather, blink facilitation to threat content only occurred at 50 ms for the high trait anxious group exclusively, and this difference was relative only to the neutral words at 50 ms. Despite supporting the notion that threat content may rapidly produce blink potentiation in highly anxious subjects, an important caveat to this study

was the finding that facilitation occurred for the *low arousing threat words only*. While it was not predicted that highly anxious subjects would exhibit greater blink facilitation to highly arousing threat content, it was expected HAT words would produce significantly more facilitation than Neutral content for both groups. This finding, however, was not observed. Further, as will be explained, the pattern obtained for neutral versus affective content at certain lead intervals was unexpected.

Contrary to expectations, blink inhibition at 240 ms was not observed in any of the affective categories. Again, it would be expected that the highly arousing pleasant or unpleasant words would produce the greatest inhibition at 240 ms, as was illustrated in Aitken et al. (1999). While few studies have examined prepulse inhibition and *word lead* stimuli, Bradley et al. (1999) found that affective *pictures* produce blink inhibition at approximately 300 ms. For *simple lead stimuli*, prepulse inhibition is largest at 120 ms, and the effect is even more robust when participants are instructed to attend to the lead stimulus.

Assuming that pictures may require greater processing, and therefore, would be expected to delay inhibitory effects of startle in contrast to simple lead stimuli, it could be that blink inhibition is not maximal at 240 ms for lexical lead stimuli. Alternatively, variability due to measurement, stimuli selection, or sampling error combined to produce the current results. While the present findings drastically depart from Aitken et al. study, there is little basis for which to conclude what the appropriate timing might be to observe blink facilitation or inhibition for lexical stimuli of varying affective valence. In addition to such factors as valence and arousal, it would be interesting to determine how word

length or word frequency contribute to the present findings, or more broadly, blink modification at short lead intervals.

Three primary methodological differences between this study and the Aitken et al's study should be noted. First, in Aitken et al's study, there were a greater number of critical trials for each of the word categories (neutral, threat). Because positively valenced stimuli, as well as words representing different levels of arousal were included in the current experiment, variability due to the number of trials in each category could have played a role in producing the current results. Second, the words in this study were unique and selected from the ANEW on the basis of normative data of valence and arousal for all subjects (males and females). Given that the majority of subjects in this study were female, perhaps normative data for females should have been used as the basis for word selection and females could have been used exclusively. Alternatively, self-reported scores of affect could have been used to validate the words, for the current sample, matched the level of valence and arousal for the category they were chosen to represent. Finally, instrumentation used for the current study was different in almost all respects to that used by Aitken et al. While this issue may not be relevant for longer lead modification experiments, the critical nature of timing for short-lead studies demands that the lead interval timing be extremely accurate. To eliminate the possibility that measurement or other sources of possible error contaminated the data, a few diagnostic steps were taken.

Instrumentation Diagnostics

Given the possibility that unchecked variability in the lead interval may have contributed to the current results, the relative accuracy of the current setup was examined in detail. Because all physical phenomena were recorded, the accuracy of the critical time

between the appearance of the lead stimulus and presentation of the pulse can be easily evaluated with a high degree of reliability. Figure 5-7 presents an intensity graph (top panel) for every trial for every subject in the present study, along with a sample trial from the physiological recording software used for data collection. To determine the relative latency between the appearance of the lead stimulus and the onset of the startle response, the information was extracted in the following manner. First, as detailed above, lead stimulus onset (i.e., the word appearing) was indicated by hardware monitoring a phototransistor mounted on the top-left corner of the screen. A small square, invisible to the participant, was positioned directly below the phototransistor, and was filled white to indicate that the lead stimulus was available for the participant to view. To ensure that the startle pulse occurred at the appropriate lead interval, a hardware-clocked counter channel was used such that its' output began once an analog threshold was reached (calibrated to be slightly less than the value of the phototransistor when the square was white). The digital waveform was created such that the pulse train was LOW (0 volts) equal to the timing of the lead interval (e.g., 40 ms) followed by a 0.5 s HIGH (5 volts), which triggered the onset of the startle pulse. Because the audio signal was also sampled, the actual lead time could be ascertained with high confidence by simply taking the time from the digital HIGH generated from the analog threshold event (square appearing white) to the time that the audio signal reached 2 SD of baseline for every trial where a pulse appeared.

As shown on the top panel, the grayscale values on the intensity graph depict the time delay in seconds between the appearance of the lead stimulus and the onset of the pulse, correcting for a given trial's purported lead interval. This color legend is shown to

the right of the graph. For all paired trials ($N = 5657$), the average margin of error equaled $89.27 \mu\text{s}$, with a standard deviation of $3.27 \mu\text{s}$. This range of error is unlikely to produce problems related to software latency shifts such that there are perceptual differences within a given lead interval.

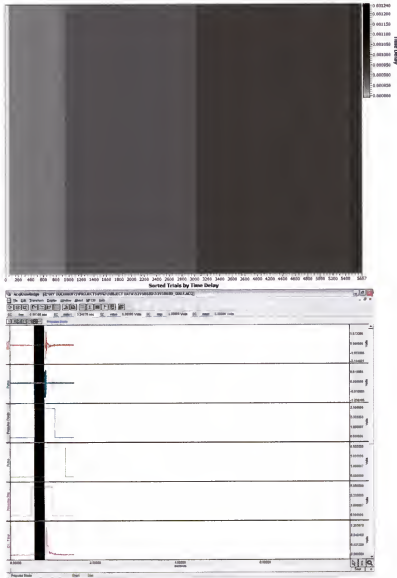


Figure 3-6. The top panel presents an intensity map of time delay between lead stimulus appearance and onset of the startle pulse in relative temporal distance from trial specified lead interval. If the lead interval for a given trial is 240 ms, then the time delay is defined by the time between the analog threshold event of the phototransistor and when the analog signal reaches 2 sd of baseline. This

interval is shown on the bottom panel, where the second channel is the digitized audio signal and the digital waveform below reflects the phototransistor triggering an analog threshold event from the data acquisition device. For this trial, the *time* Δ is .24076 s, with an overshoot of 76 μ s.

A third objective was to determine whether the blink facilitation observed in Aitken et al's study was specific to threat, or whether it is a function of arousal. To investigate this issue, both negative and positive lexical lead stimuli representing both high and low levels of arousal were included. Greater blink facilitation was hypothesized for threat relative to pleasant content at the 60 ms lead interval. An unexpected finding was that highly trait anxious subjects exhibited significant blink facilitation to low arousing pleasant words at 50 ms relative to neutrals at 50 ms and compared to low anxious controls. While this finding partially supports the view that short lead startle to words at 50 ms are purely sensory in nature, this view cannot be fully supported given that blink facilitation did not occur for other categories at this or the 40 ms lead interval. An interesting question then is why did blink facilitation occur for both low arousing unpleasant and pleasant content at 50 ms for the highly trait anxious participants exclusively?

Perhaps blink facilitation at the 50 ms lead interval can be attributed to both attentional and sensory processes. For example, low anxious controls exhibited blink inhibition for highly arousing pleasant content at 60 ms. If facilitation was a product of arousal at the 40, 50, and 60 ms lead intervals, prepulse facilitation would be expected independent of affective category and similarly by level of arousal. One possibility for the variability across different word categories may have to do with how words are processed as opposed to their affective dimensions.

A recent study investigating attentional processing to emotional words and names (Harris & Pashler, 2004), suggested that studies reporting differential findings with respect to attentional manipulations do so primarily because the number of trials will often vary and the rate at which habituation occurs for different affective categories varies across trials. The researchers employed a digit parity task described by Wolford and Morrison (1980). In this task, a word is flanked by two digits, and subjects are asked to respond (keypress) to whether the digits are both odd or even. Harris and Pashler, however, modified the task, replacing a person's name on critical trials (Experiment 2) with negatively valenced words. The experiment was arranged such that in the first block, two negatively valenced words presented on trials 30 and 40 of 50 total trials would contain the critical word, and in a second block, half of the trials would contain critical trials. While reaction time on the parity task was significantly slower on the two critical trials in the first block, there was a significant increase in response time from the first critical presentation to the second critical presentation (i.e., rapid habituation to the negative content). In the second trial block, negative words and neutral words did not significantly differ. The authors concluded that while emotional words produce interference during a primary task, their influence rapidly disappears with multiple presentations of similar stimuli.

Considering Harris and Pashler's results, it could be that blink facilitation to threat occurred in the predicted direction for highly trait anxious subjects, however, averaging of a number of trials obscured this effect. To examine this issue more closely, results were reanalyzed and exploratory analyses completed by introducing Trial Block as a

factor. While a significant Group x Category x Trial Block interaction emerged⁹, this effect was not explored further because it does not shed light on the critical question of whether blink facilitation occurs more rapidly or more robustly for highly trait anxious subjects. To further investigate whether the results of the present study could have been masked even with a single block of trials, exploratory analyses were again conducted using the first exposure to a given exemplar. This analyses produced a number of significant interactions, but the critical interaction of Group x Category x Lead Interval only approached significance.¹⁰ It should be noted, that the findings in the second analysis only occur if the ITI used to compute the proportion of difference measure is an average of entire testing session. If the first exposure to the ITI is used, then the above results disappear.

Limitations

Several limitations of this study need to be considered as a basis for future research. Because researchers have yet to establish findings as they pertain to short lead interval startle modification to lexical lead stimuli, extrapolating the meaning of the current results is limited given that the findings did not adhere to the underlying postulated framework. That is, the expectation of blink inhibition at 240 ms for affective lead stimuli compared to neutrals, for example, would be predicted to occasion inhibition for both groups, irrespective of anxiety. However, while it is reasonable to assume that blink inhibition should occur for highly arousing words compared to low arousing words at lead intervals of around 240 ms, this prediction could be obscured by other factors

⁹ $F(3.70, 204) = 2.54, p < .05$

¹⁰ $F(7.77, 403.79) = 1.94, p = .055$

mentioned such as word length, word frequency, or a person's level of reading comprehension. As such, a major limitation in this study was that the original effect observed in the Aitken et al (1999) experiment was not replicated.

While elements which may have lead to this discrepancy have been explored in this section, another critical issue that should be considered is the number of exemplars used to represent the various categories. Though it is difficult to establish an exact number of trials to firmly conclude that within-condition variability will not be a limiting issue, it may have been the case for the current experiment. As such, the effects reported here are likely to contain a greater degree of variability in estimates of blink magnitude for each of the affective categories.

The amount of participant *interest* is also an issue with many experiments, and it is a difficult balance to obtain enough trials to be representative of a given condition while also considering how fatigue or boredom may adversely affect the experimental outcome. Thus, although the experiment was not excessively long, the task itself is a limiting factor, given that looking at words for thirty minutes in a dark room may have proven too difficult to maintain attention for some subjects. While some participants reported that they were sleepy near the end of the experiment, others reported little or no fatigue. In this experiment, the major question was to determine whether highly anxious participants occasion greater blink facilitation at very short intervals following presentation of threatening stimuli than controls. The use of lexical lead stimuli, however, is but one stimulus set that could be used to evaluate the speed at which a threat is acquired and the defense system initiated. The use of images and classically conditioned

cues, for example, could both serve as viable lead stimuli to investigate the major issue more closely.

Directions for Future Research, Summary, and Conclusions

Explaining the temporal chronometry of attentional allocation and accounting for individual differences in the perception of threat represent two of the major theoretical challenges to cognitive based theories of anxiety. While this study partially focused on the time course of processing negative stimuli and how anxiety may be associated with enhanced processing to threat, other researchers have focused on how attention may be allocated when competing (threat versus neutral) stimuli appear in the visual field exclusively. However, a primary interest in this investigation was to evaluate attentional bias in absence of the commonly used behavioral techniques implementing interference or probe detection based paradigms. The attempt to employ startle modification methodology to investigate attentional bias in anxiety is an important step in furthering our understanding of how attentional systems behave under different levels of anxiety on a different level of analysis than what has been traditionally employed. Thus, results reported in the Aitken et al (1999) study need to be replicated with a different word set, with the inclusion of pleasant stimuli to exclude the possibility that the effect of early processing to threat is not a product of arousal, and with lead intervals occurring prior to 60 ms to determine when blink facilitation begins due to defensive priming (i.e., not an artifact of temporal summation).

Given that the findings in the Aitken and colleagues study can be replicated, another interesting area for future research would be to determine whether alternative diagnosis of anxiety exhibit a similar trend when exposed to their individual anxiety-engaging content. For example, this might also include replicating Globisch et al. (1999)

finding for faster and more pronounced blink facilitation for animal (i.e., snake and spider) fearful participants compared to controls using paradigms that employ backward masking techniques, or to see if the effect also occurs for lexical stimuli.

To summarize, the study only weakly supported the finding that highly trait anxious participants occasion greater blink facilitation to threat. While blink facilitation to threat content was observed at 50 ms relative to neutral words at the same lead interval for the high trait anxious group exclusively, blink facilitation for this group was also observed for low arousing pleasant words at 50 ms, which was not expected.

APPENDIX A
INSTITUTIONAL REVIEW BOARD APPROVAL



UNIVERSITY OF
FLORIDA

Institutional Review Board

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DATE: February 21, 2005

TO: Aaron R. Duley & Christopher Janelle, PhD
PO Box 118205
Campus

FROM: Ira S. Fischler, Ph.D., Chair *isf*
University of Florida
Institutional Review Board 02

SUBJECT: **Approval of Protocol #2005-U-0142**

TITLE: *Startle eyeblink modification and anxiety: Short lead interval startle indexes early affective processing of lexical stimuli*

SPONSOR: None

I am pleased to advise you that the University of Florida Institutional Review Board has recommended approval of this protocol. Based on its review, the UFIRB determined that this research presents no more than minimal risk to participants. Given your protocol, it is essential that you obtain signed documentation of informed consent from each participant. Enclosed is the dated, IRB-approved informed consent to be used when recruiting participants for the research.

It is essential that each of your participants sign a copy of your approved informed consent that bears the IRB stamp and expiration date.

If you wish to make any changes to this protocol, including **the need to increase the number of participants authorized**, you must disclose your plans before you implement them so that the Board can assess their impact on your protocol. In addition, you must report to the Board any unexpected complications that affect your participants.

If you have not completed this protocol by February 21, 2006, please telephone our office (392-0433), and we will discuss the renewal process with you. It is important that you keep your Department Chair informed about the status of this research protocol.

APPENDIX B INFORMED CONSENT

Informed Consent to Participate in Research
Department of Applied Physiology and Kinesiology
Gainesville, FL 32611

You are being asked to participate in a research study. This form provides you with information about the study. The Principal Investigator (the person in charge of this research) or his/her representative will also describe the study to you and answer all of your questions. Read the information below and ask questions about anything you don't understand before deciding whether or not to take part. Your participation is entirely voluntary and you can refuse to participate without penalty or loss of benefits to which you are otherwise entitled.

Title of Research Study

Understanding the time course of attention

Investigator(s) and Institutional Review Boards Contact Information

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Sponsor of the Study

N/A

Approved By University of Florida Institutional Review Board 02 Protocol # 2005-U-0142 For Use Through 2/21/2006
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What is the purpose of the study?

The purpose of this research is to examine emotional responses to different kinds of words and, in addition, to determine whether different emotions affect attention. In this experiment, you will view a series of words that have been previously been judged as pleasant, neutral, or unpleasant in content. During the word viewing session, a brief noise click may be presented to you through headphones you will be wearing. You just can ignore the clicks. During the experiment, your physiological reactions will be recorded through the use of sensors

placed on your skin. Your experimenter will explain to you where these sensors will be placed. These sensors are both harmless and painless- they merely will record the electrical signals produced by your body. The entire session will take about 1 hour.

Following the testing session, you will be asked to respond to questionnaires that explore psychological illness and well-being. If, for any reason, you would like to consult with Mental Health Counselors, a referral will be given.

What are the possible discomforts and risks?

The risks involved in this study are minimal, and are the same as the minimal risks inherent in a routine clinical examinations involving measurement of bodily activity (i.e., heart, muscle, brain, skin, etc.). Application of the sensors to the body poses minimal problems. A sensor is applied 1) by first cleaning the skin by rubbing briskly with a tissue, 2) applying a jelly, and 3) attaching the sensors to the skin with a tape-like collar. Individuals with high sensitivity to cosmetics or creams, or extreme skin allergies may find that a short-lived redness at certain sites develops after the sensors are applied, although most people find the procedure harmless. The possibility of infection at any site where sensors are applied is non-existent in most cases, and minimal at most, as proper cleaning and sterilization procedures are implemented at all times.

If you wish to discuss these or any other discomforts you may experience, you may discuss them with the experimenter.

What are the possible benefits to others?

After the session is over, you will be informed in detail about the design and hypotheses involved in this experiment. In addition, you will have the opportunity to ask questions; thus, you will benefit by learning something about psychological research. While you, as the participant, may not receive direct benefits from taking part in this study, the results may lead to recommendations for the increased mental health and effective functioning of adult individuals.

If you choose to take part in this study, will it cost anything?

Participation in this study will cost you nothing.

Will you receive compensation for your participation in this study?

You will be eligible to receive extra credit from your course instructor that can total no more than 2% of your final grade.

How will your privacy and the confidentiality of your research records be protected?

Only the principle and co-investigator(s) will have access to your records. Further, any information regarding your participation will be arranged such that you will be identified by number only. Your identity will be kept confidential to the extent provided by law. Questions or concerns about research participants' rights may be directed to the U-IRB Office, Box 112250, University of Florida, Gainesville, FL 32611-2250 (392-0433).

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Will the researchers benefit from your participation in this study (beyond publishing or presenting the results)?

No.

Signatures

As a representative of this study, I have explained the purpose, the procedures, the benefits, and the risks that are involved in this research study:

Signature of person obtaining consent

Date

You have been informed about this study's purpose, procedures, possible benefits and risks, and you have received a copy of this form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask questions at any time. You voluntarily agree to participate in this study. By signing this form, you are not waiving any of your legal rights.

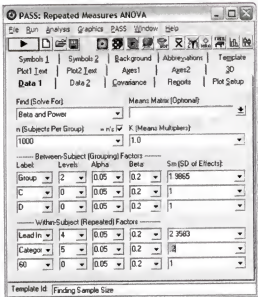
Signature of Participant

Date

Approved By
University of Florida
Institutional Review Board 02
Protocol # 2005-U-0142
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APPENDIX C
POWER CALCULATION FOR MULTI-FACTOR MIXED DESIGNS

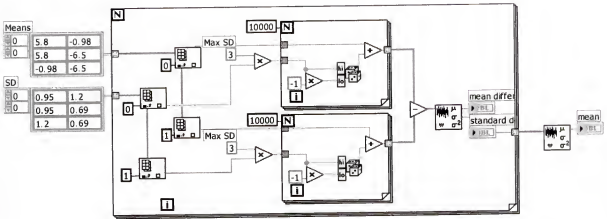
Power estimates for the study’s multi-factor mixed design were computed using a program called PASS (Power Analysis and Sample Size, NCSS, Kaysville, UT, see figure below).



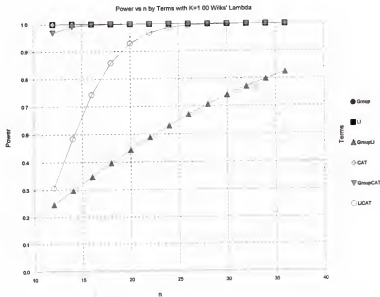
PASS requires several pieces of information in order to solve for statistical power. First, the design must be specified. This step includes the completion of (a) both the between- and within-subjects factors, (b) the number of levels for each factor, (c) the desired beta coefficient, and (d) the estimated standard deviation of the effects (SDe).

Simulated SDe values were generated for the current study by simulating data based from Aitken et al’s (1999). To compute SDe, means and standard deviations for each factor of interest were used to compute 10,000 result estimates by randomly creating values falling ± 3 standard deviations from the Aitken et al. factor mean. Thus, if the

mean was 5 and had a standard deviation of 1, then 10,000 values would be randomly generated falling within -3 and 3 of this value. These values were averaged and this step repeated for each level of a given factor. This step was accomplished using a LabVIEW (see figure below).



Once the SDe values were computed and the values entered into PASS, a plot is produced which produces statistical power as a function of sample size (see figure below).



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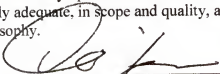
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BIOGRAPHICAL SKETCH

Aaron Robert Duley was born on Friday, September 17, 1976, in San Jose, California. Following years of elementary public education, Aaron attended Herman Junior High, where he would meet his future wife Susie Le. Upon graduating from Oak Grove High School High School in 1994, Aaron attended De Anza Community College where he pondered the drawbacks of limited academic concern during his pre-collegiate education. Following his brief Junior college tenure, Aaron attended San Jose State University, where in 1999 he would graduate with a Bachelor of Arts degree in Psychology. Prior to graduation, Aaron enrolled in a psychology course taught by Thomas Tutko, who was a pioneer in the field of Sport Psychology and who inspired him to continue his educational pursuits in the area of human performance and expertise. Subsequently, he began his graduate work in Sport and Exercise Psychology at the University of Florida under the advisement of Christopher M. Janelle. Upon graduation with his doctoral degree in Applied Physiology and Kinesiology, Aaron accepted a postdoctoral position in a human factors research laboratory at the University of Central Florida.


I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.


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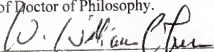

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